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Основная тематическая направленность журнала: материалы о научно-технических, организационных, экономических, экологических, правовых проблемах, истории, состоянии и перспективах развития транспортного комплекса стран БРИКС; о взаимодействии стран БРИКС по вопросам транспортного обеспечения и сотрудничества с другими государствами, мировыми транспортными системами, а также о подготовке персонала всех уровней для транспортной отрасли и развитии в данной сфере сотрудничества образовательных учреждений и транспортных предприятий разных стран.

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CONTENT

СОДЕРЖАНИЕ

On August 22–24, the XV BRICS Summit was held in Johannesburg, South Africa, with the participation of Brazilian President Lula da Silva; President of the Russian Federation Vladimir Putin (via videoconference) and Russian Foreign Minister Sergey Lavrov in person; Prime Minister of India Narendra Damodardas Modi, President of China Xi Jinping, President of South Africa Matamela Cyril Ramaphosa.

South African President Matamela Cyril Ramaphosa, as Chairman of the Association during this period, invited leaders from 67 countries, including more than 60 heads of state and government from Africa, and developing countries from other regions of the world: Bangladesh, Bolivia, Indonesia and Iran.

A year earlier, at the BRICS foreign ministers' meeting on May 19, 2022 via videoconference, China proposed to start the process of BRICS enlargement to *"enhance the Association's representation and influence in the world"*[1].

By the beginning of the XV Summit, a number of countries had applied to join the organisation, including Argentina, Iran (announced in June 2022), Algeria (in November 2022), Saudi Arabia, UAE, Bahrain, Egypt (in May 2023); Bangladesh, Ethiopia (in June 2023), and Venezuela (in August 2023). Several other states have officially expressed their interest in joining the format.

Johannesburg. Nelson Mandela Monument in front of Sandton City Centre in the square named after him

[1] What is known about BRICS Association // TASS. URL: https://tass.ru/info/18558683

The University of Johannesburg. Kingsway Campus

BRICS leaders adopted the final Second Johannesburg Declaration at the XV BRICS Summit[2]. According to the document, six countries – Argentina, Egypt, Egypt, Ethiopia, Iran, Iran, Saudi Arabia and the UAE – will join BRICS from 2024. The participants of the Summit agreed to prepare a new list of possible partners for the next meeting. South African President Matamela Cyril Ramaphosa said that BRICS has opened a new chapter in its history.

BRICS participants are in favour of keeping the name of the association after expanding the number of participants, Russian Foreign Minister Sergey Lavrov said. *“Everyone is in favour of keeping the name, it has already become a brand. None of the new entrants to the BRICS ranks suggested otherwise”*, he said at a press conference following the organisation’s summit in South Africa[3, 4].

“BRICS leaders have had the opportunity over the past two years to negotiate through videoconferences as well as a full-fledged summit”, South African President Matamela Cyril Ramaphosa said on August 24. “As a result of these talks, we have agreed to adopt the Johannesburg Declaration. This document covers a wide range of issues presented to the leaders, which were negotiated over nearly a year. The work was done by our experts and ministers. As a result, we have adopted this document. This is the Johannesburg Declaration No.2, and it has been adopted”[5].

Russian Foreign Ministry spokeswoman Maria Zakharova said the results of the summit were brilliant. *“Isolation” as an American weapon has been defeated forever”*, she wrote in her Telegram channel5. Russia, as chair of BRICS next year, intends to hold the BRICS summit in Kazan in October 2024.

In his speech at the XV BRICS summit at the enlarged leaders’ meeting on August 23, 2023, Russian President Vladimir Putin drew attention to the issues of transport development in the BRICS countries and their cooperation in this area. Putin drew attention to the issues of transport development of the BRICS countries and their cooperation in this area, in particular, he said: *“An important priority of BRICS cooperation is the creation of new sustainable and safe transport routes. Speaking before the BRICS Business Forum, I have already spoken about the urgency of accelerated development of transcontinental routes, such as the North-South corridor, which will connect Russian ports in the northern seas and the Baltic Sea with sea terminals on the Persian Gulf and Indian Ocean coasts and in the future will be able to ensure annual transit of up to 30 million tonnes of cargo.*

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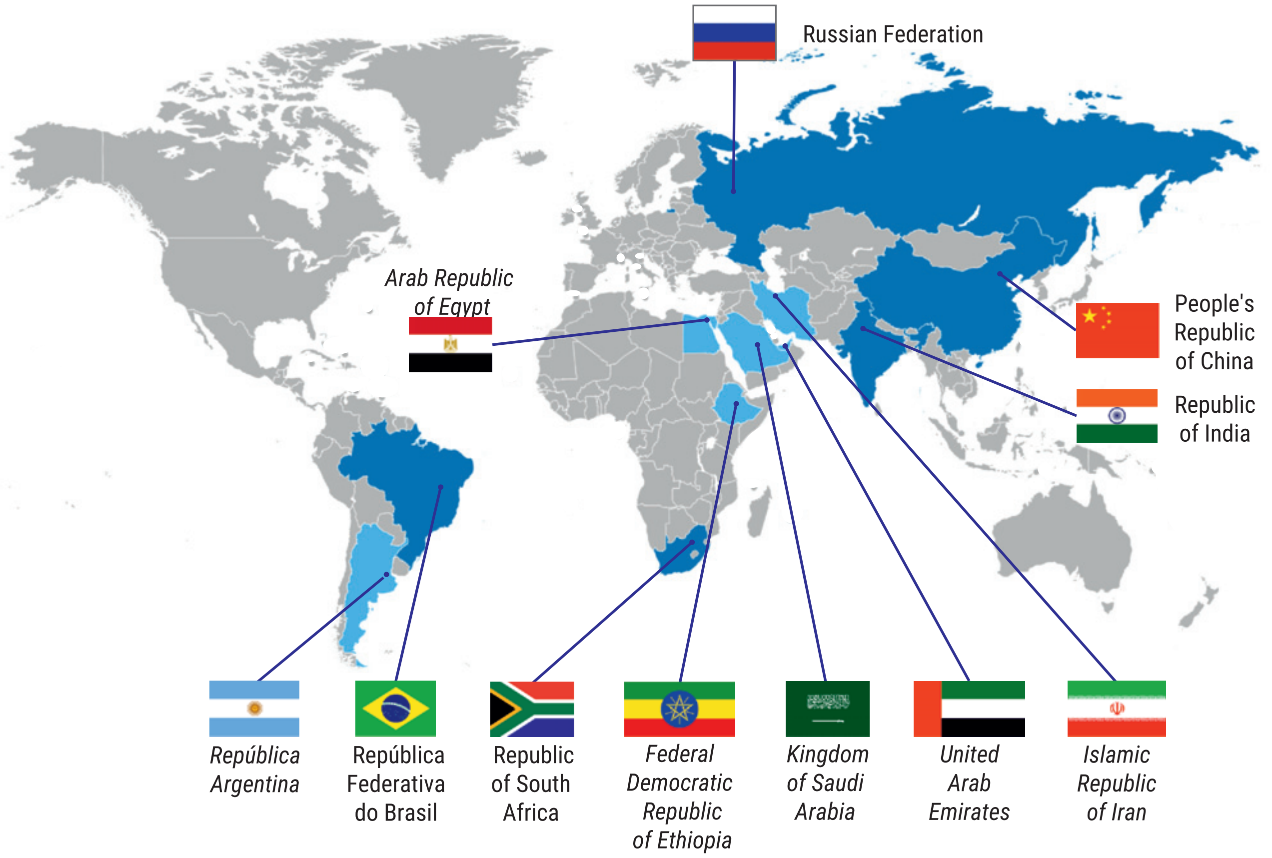
[2] On July 25–27, 2018, the X BRICS Summit was held in Johannesburg, South Africa, which adopted the Johannesburg Declaration, now referred to as the First Johannesburg Declaration.

[3] Interestingly, in Chinese, the name of the BRICS Association is denoted by a character 金砖 (pronounced in English as jīn zhuān) and is read “golden bricks”.

[4] BRICS will retain its name after six more countries join // RIA Novosti. URL: https://ria.ru/20230824/briks-1891989485.html

[5] BRICS countries adopted the Johannesburg Declaration at the end of the 15th summit.



BRICS countries. The names of the countries invited to the BRICS following the XV Summit, whose membership will begin in 2024, are typed in italics[7]

We believe that the time has come to establish a permanent transport commission within the BRICS framework that would deal not only with the North-South project, but also more broadly with the development of logistics and transport corridors, interregional and global. If the partners agree, the Russian side could work on this idea within the framework of the BRICS Chairmanship in 2024"[6].

Based on open sources
Photo by Egor Komarov
Drawing of flags in the header – source: https://internationalbanker.com/finance/why-the-brics-bloc-will-play-a-crucial-global-economic-role-in-2023/

* * *

"Summer School – 2023" for international students was organised in August 2023 by the Emperor Alexander I St. Petersburg State Transport University (PGUPS) with the support of Eurasia International Corporation. As part of the traditional summer programme for foreigners, a seminar for PRC students studying Russian as a foreign language was held. The seminar was attended by students of Nanjing Institute of Railway Technology (the People's Republic of China), with which

Chinese students in front of the monument to the organiser and First Rector of the University Augustin de Betancourt in front of PGUPS building (PGUPS Press Service)

[6] BRICS Leaders' Enlarged Meeting. URL: http://kremlin.ru/events/president/news/72089
[7] Collage by E. Komarov on the basis of contour map (URL: https://upload.wikimedia.org/wikipedia/commons/6/6b/Map_of_BRICS_countries.svg)

PGUPS maintains long-term cooperation on the basis of a long-term agreement. The students from China were taught according to the programme of specially organised master-classes of intensive Russian language learning with immersion in the language environment by experienced teachers. In addition to classroom classes, the programme included excursions in Russian to the university, Saint Petersburg and its surroundings.

It is planned that next academic year the Chinese students who participated in the Summer School will join the ranks of PGUPS students and start studying the bachelor's degree programme "Electric Power Engineering and Electrical Engineering".

* * *

On August 24–27, 2023, the International Railway Salon "PRO//Movement.Expo" was held in Saint Petersburg. This important event in the field of railway transport was held for the first time on the site of the Museum of Russian Railways in Saint Petersburg. Samples of new equipment were presented on the area of more than seven thousand square metres – in the covered pavilion, on the open area and on the railway tracks. The event was attended by more than 130 companies, including 15 foreign ones, in particular, the car-building enterprise Jinxi Axle Co. Ltd. and a manufacturer of railway special machinery, particularly construction machinery, Shandong Huasheng Zhongtian Engineering Machinery Co. Ltd. of the People's Republic of China.

The exposition included 42 units of railway equipment, including more than 30 locomotives and cars, as well as new electric trains.

Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways", JSC, together with other company executives, inspected the exhibits. Among the latest developments at the exhibition were presented: hybrid contact-battery DC electric locomotive EMKA2; a new modification of electric train EGE2Tv "Ivolga 4.0"; DC electric train EP2DM; electric locomotive 3ES8 "Malakhit", which will become the basic platform for the development of the family of electric locomotives; a model of a prospective capsule passenger car in the dimension of the rolling stock T; a model of the updated interior of the SV car and other exhibits.

The PRO//Movement.Expo business programme included round tables, panel discussions, reports and communications devoted to the problems of achieving technological independence of the domestic railway engineering industry, development of digital technologies, the latest trends in transport logistics and issues of international cooperation strategy.

An important event of the business programme was the panel discussion "Prospects for the Development of Transport and Railway Engineering. Image of 2030", in which Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways", JSC, took part and made a presentation.

The participants in the discussion presented their vision of the industry's development in the near future in the context of sanctions restrictions and assessed the importance of consolidating efforts and co-operation with transport engineering leaders from friendly countries.

According to Oleg Belozerov, in order to maintain and strengthen its leading position, Russian Railways, together with machine-building holdings, will have to ensure the development and implementation of a number of innovative technologies by 2030: hydrogen propulsion systems, unmanned steering and high-speed railways.

In his speech, Sergey Kobzev, the First Deputy General Director of "Russian Railways", JSC, said that the share of foreign components in the Russian rolling stock currently does not exceed 6 %, and only 6,000 out of 200,000 units of design documentation are supplied

General view of the complex of pavilions and full-scale exhibits of the Museum of Russian Railways in Saint Petersburg

Panel discussion "Innovations. Vector of Cooperation"

Roundtable "The Russian Labour Market: Staff Training at Universities and Competition for Talent among Employers"

by foreign companies[8]. "Russian Railways", JSC, together with machine-building companies, is certifying and organising serial production of new domestic models that will replace imported component parts.

Dmitriy Pegov, General Deputy Director of "Russian Railways", JSC and Head of the Traction Directorate, spoke about import substitution programmes using the example of electric trains. *"We organised the maintenance of Sapsan and Lastochka trains using our own resources in almost a month – in the shortest possible time we set up our own company, which took the initiative to carry out maintenance, and the process of transition to maintenance of trains exclusively using our own resources is proceeding as planned"*[8].

Effective discussions were devoted to the prospects of domestic car building. Dmitriy Pegov, Deputy General Director of "Russian Railways", JSC, together with representatives of manufacturing companies, presented a model of passenger carriages taking into account passenger demands. At present, the possibility of developing a permanent passenger train of the Push-Pull type consisting of a two-system electric locomotive, double-deck cars and a double-deck end car with a control cabin is being considered.

Representatives of railway enterprises and industry-specific universities showed great interest in the round table "The Russian Labour Market: Staff Training at Universities and Competition for Talent among Employers". It was attended by major experts in the field of transport staffing, including Dmitriy Shakhanov, Deputy General Director of "Russian Railways", JSC, and Oleg Valinskiy, Rector of PGUPS.

Dmitriy Shakhanov noted that in order to attract new employees, the holding company has developed

[8] The International Railway Salon "PRO//Movement.Expo: took place in Saint Petersburg on August 24-27. URL: https://railwayforum.ru/news/?ID=13011

Dmitriy Shakhanov (left) and Oleg Valinskiy, participants of the roundtable "The Russian Labour Market: Staff Training at Universities and Competition for Talent among Employers"

a set of tools under the general name "Russian Railways – for people of business", he also formulated the key advantages of the company as an employer: scale, technology and care for employees[7].

The exposition of the Emperor Alexander I St. Petersburg State Transport University at the exhibition of the salon was unfolded, where the developments of the University's employees and students were presented, in particular, a pilot plant made by students of the Department of Locomotives and Locomotive Maintenance, with the consulting assistance of the Department of Electrical Engineering and Heat Engineering. The essence of the device proposed by students Danil Taritsin, Danil Orlov and Alexander Petukhov is to create a non-contact drive using permanent magnets for locomotive auxiliary devices, for example, compressors and fans of the diesel refrigerator.

A number of agreements between business partners were signed during the PRO//Movement.Expo salon. In particular, the Emperor Alexander I St. Petersburg State Transport University signed a cooperation agreement with Joint Stock Company "Research Institute of Railway Transport" ("VNIIZhT", JSC), which provides for mutually beneficial cooperation aimed at the development of educational, scientific, innovative and research activities of PGUPS, improving the quality of training and retraining of personnel for railway transport. The parties intend to participate in the consortium within the framework of cooperation under the Priority 2030 strategic academic leadership programme and the development of technological leadership in the target areas of activity established by this programme.

The University also signed a plan of joint work until 2025 with the car building company "MC RM Rail", LLC. The plan provides for a wide range of joint scientific, academic, cultural and educational activities aimed at research in the field of car design and production and training of specialists for the industry.

On August 26–27, after the official part of the PRO//Movement.Expo salon, designed for specialists, Open Road Days were organised for all interested citizens and guests of Saint Petersburg. The complex of the Museum of Russian Railways and exhibition grounds were visited by more than 11 thousand people. On the platform tracks of the Baltiyskiy railway station there was organised a display of operating machinery: steam

PGUPS students demonstrate their presentation of experimental plant of non-contact drive with permanent magnets (pictured in the foreground, left to right): Danil Taritsin, Alexander Petukhov and Danil Orlov

Tamila Titova First Vice Rector, Vice Rector for Scientific Work during the presentation of experimental plant of non-contact drive with permanent magnets. Alexander Petukhov (left) and Danil Orlov (right), the students of Emperor Alexander I State Transport University present the plant

Sergey Vinogradov (left), General Director of VNIIZhT, and Oleg Valinskiy, Rector of PGUPS, sign the co-operation agreement

After signing the plan of joint work until 2025, “MC RM Rail”, LLC and PGUPS – exchange of signed documents and handshake: General Director of “MC RM Rail”, LLC Maksim Teves (left) and Rector of PGUPS Oleg Valinskiy

locomotives of CO and P36 series, electric locomotives of CS2 and CS6 series and other locomotives.

The guests of the Open Road Days were welcomed with various excursions, thematic exhibitions for adult visitors and children of different ages, and quizzes.

Visitors could watch the parade of operating vintage steam locomotives, electric and diesel locomotives, as well as new developments of rolling stock, which Russian railway workers are proud of, from the stands along the railway tracks.

Photo report

THE OPEN ROAD DAYS

Lectures and excursions

Classes for young visitors of the exhibition on training facilities (simulators) and business games

Children's railway drawing competition, games and quizzes

Parade of Locomotives

The PRO//Movement.Expo Salon has become an important event not only in scientific, engineering, economic, but also cultural life of Russia and Saint Petersburg.

Based on the materials of "Gudok" Publishing House (URL: https://railwayforum.ru/news/?ID=13011). Photo provided by the Corporate Communications Service of the Oktyabrskaya Railway, a branch of Russian Railways, and the press service of the Museum of Russian Railways.

* * *

As part of the Moscow Urban Forum, the BRICS International Innovation Forum was held in Moscow on August 27–29, 2023, which brought together more than 4,000 participants from 30 countries. The business programme, which included 50 thematic sessions, featured more than 130 Russian-speaking and 70 foreign speakers from the UAE, Saudi Arabia, China, Japan, Serbia, South Africa, India and other countries.

The forum addressed the issues of sustainable development of the urban environment, including transport problems, various aspects of social and economic life of modern megacities.

The business platforms became the place to discuss the basics of creating a “cloud city”, which will help to make a smart urban “revolution” oriented towards economy, state and person.

The business programme “Human” dealt with the issues of sharing economy, new services and services. The Economy programme offered a new perspective on the development of infrastructure, services and scientific and technical research. The panel discussions focused on the topics of digitalisation and cloud infrastructure of cities, economics and technological transformation of urban and banking services that are changing our lives. A separate discussion was held on the issue of “Technology for Human or Human for Technology”.

PGUPS was represented at the forum by Andrey Lang and Nikita Labutin, graduate students of the Bridges Department, and Tatiana Ageeva and Alina Yurchenko, master’s students, who presented their reports.

Panel discussion at the forum


International Forum participants Alina Yurchenko (left) and Tatiana Ageeva

PGUPS Press Service (PGUPS photo)

* * *

On September 1, 2023, the Emperor Alexander I St. Petersburg State Transport University held a solemn ceremony dedicated to the Day of Knowledge. According to the established tradition, the holiday was held in the square of the Yusupov Palace on the Fontanka River.

Rector of PGUPS Oleg Valinskiy addressed the first-year students with a farewell speech: *“This is a particularly exciting day for me, because I am also a first-year student, for me it is the first academic year in a new position at our wonderful university. A university that has a history of 214 years. During these years it has been increasing its competences, training specialists for the railways, metro and other important enterprises of our Motherland. I think that you, as students joining our staff, will support the traditions existing in the university, become talented specialists and increase the glory of the Leningrad Institute of Railway Engineers”.*

The palace of the Yusupov Princes on the Fontanka embankment in Saint Petersburg. Architect G. Quarenghi, late 18th century. On November 1, 1810, students of the first engineering transport university in Russia – now Emperor Alexander I St. Petersburg State Transport University (PGUPS) – began their studies in this building. The garden of the Yusupov Palace (Yusupov Garden) traditionally hosts university students' festivals. Photo by Egor Komarov

From left to right: guests of honour: Viktor Golomolzin, Head of the Oktyabrskaya Railway – a branch of "Russian Railways", JSC; Nikita Kamenir, Head of the North-West Territorial Administration of the Federal Railway Transport Agency; Oleg Valinskiy, Rector of PGUPS; Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways", JSC; Kirill Polyakov, Vice-Governor of Saint Petersburg; Natalia Astakhova, Member of the Legislative Assembly of Saint Petersburg; Denis Shevchenko, Transport Prosecutor of Saint Petersburg, and Evgeniy Kozin, Head of the Saint Petersburg Metro. Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways" is reporting his speech

First-year students of PGUPS at celebration of the Day of Knowledge

Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways", JSC, Chairman of the Board of Trustees of PGUPS, said: *"Dear friends, the fact that you are here today is already a certain success, you have passed the entrance tests, you have decided on your future profession. Now our task is to persuade you to come to our company after graduation. Russian railways are developing, and each of you will find interesting and promising work for energetic people, for people of business. Railways move by people's energy and we need your energy and knowledge very much".*

The part of the celebration adapted for stage. The symbolic student card is handed over by the university rector Oleg Valinskiy and the university organiser Augustin de Betancourt, performed by Associate Professor Evgeniy Korovyakovskiy

The symbolic flame of knowledge is lit by Nikolay Bushuev, an honourable teacher of PGUPS

According to tradition, first-year students laid flowers at the monument to the monument to the organiser of the university, the First Rector Augustin de Betancourt

The audience was greeted by the guests of honour: Nikita Kamenir, a graduate of PGUPS, Head of the North-West Territorial Department of the Federal Railway Transport Agency; Kirill Polyakov, Vice-Governor of Saint Petersburg; Evgeniy Kozin, a graduate of the university, head of Saint Petersburg Metro, who congratulated professors, teachers and students on the Day of Knowledge and wished them success.

In the theatrical part of the holiday the organiser and the First Rector of the University, Engineer, Architect, Scientist Augustin de Betancourt, whose role was played by Associate Professor Evgeniy Korovyakovskiy, addressed the first-year students. By his decree he ordered to light the symbolic fire of knowledge "as an eternal symbol of the movement from the darkness of ignorance to the light of knowledge", which was performed by Nikolay Bushuev, an honourable lecturer of PGUPS.

At the end of the celebration, Rector Oleg Valinskiy presented representatives of first-year students with a symbolic student ticket. The 214th academic year began at the Emperor Alexander I St. Petersburg State Transport University.

Egor Komarov. Photo of PGUPS

* * *

A regular meeting of the Board of Trustees of the Emperor Alexander I St. Petersburg State Transport University was held on September 1 under the chairmanship of Oleg Belozerov, General Director and Chairman of the Management Board of "Russian Railways". JSC.

They considered the following issues: the results of implementation of the Development Programme of the Emperor Alexander I St. Petersburg State Transport University for 2019–2023 in 2019–2022; joint activities of PGUPS and "Russian Railways", JSC, for advanced training of specialists; preparation for the events scheduled for 2024 dedicated to the memory of Augustin de Betancourt – the First Rector of the Leningrad Institute of Railway Engineers, General Director of Railway Engineering of the Russian Empire (to the 200th anniversary of the death of A.A. de Betancourt on 26 July 2024). Specific decisions were made on the issues considered.

The meeting approved the new composition of the Board of Trustees: Oleg Belozerov – General Director and Chairman of the Management Board of "Russian Railways", JSC, Chairman of the Board of Trustees of PGUPS; Oleg Valinskiy – Rector of PGUPS; Vladimir Garyugin – Honorary Citizen of Saint Petersburg; Viktor Golomolzin – Head of the Oktyabrskaya Railway – branch of "Russian Railways", JSC; Aleksey Druzhinin – Head of the Federal Agency for Railway Transport; Evgeniy Kozin – Head of the State Unitary Enterprise "Saint Petersburg Metro"; Anatoliy Krasnoshchek – Senior Advisor to the Director General of "Russian Railways", JSC; Jakob Kraft, General Director of Yamal Railway Company; Kirill Lipa, General Director of "Transmashholding", JSC; Viktor Lobko, President of PGUPS Alumni Corps; Kirill Polyakov, Vice-Governor of Saint Petersburg; Igor Romashov, Chairman of the Board of Directors of "Transoil", LLC, Chairman of the Board of Trustees of the PGUPS Development Assistance Fund; Valeriy Tanaev, Head of Moscow Railway, a branch of "Russian Railways", JSC. PGUPS Professor Igor Kiselev was reappointed Secretary of the Council.

Meeting of the Board of Trustees of the Emperor Alexander I St. Petersburg State Transport University, 1 September 2023, St. Petersburg. Photo by PGUPS

PGUPS Press Service

Presentation of Russian Transport Universities
Представляем российские транспортные университеты

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Emperor Alexander I St. Petersburg State Transport University is the first engineering and transportation university in Russia. It was founded on November 20 (December 2), 1809, by the Manifesto of Emperor Alexander I, the highest state legal act, as the Institute of the Corps of Railway Engineers. The first rector (inspector) and organizer of the Institute – Augustin Betancourt (1758–1824) – an outstanding engineer, scientist, architect and builder, statesman of Spain and Russia, was invited to serve personally by Emperor Alexander in 1808.

From 1924 the University was called the Leningrad Institute of Transport Engineers, from 1930 it was called the Leningrad Institute of Railway Engineers (LIIZhT), on the basis of its faculties four independent universities were created: the Leningrad Institute of Water Transport Engineers (1930), Leningrad Institute of Civil Air Fleet Engineers (1930), Leningrad Road Institute (1931), and Military Transport Academy (1938).

In 1993, LIIZhT received the status of a university and its modern name; in 2014, the name of its founder, Emperor Alexander I, was returned to the name of the university. Initially, the Institute trained railway specialists of a wide profile. In the late 1830s, in connection with the beginning of the construction of railways in Russia, special sections related to the new type of transport – the most advanced in the XIX century – railway – were included in the curriculum of the course of construction art.

The activity of professors and graduates of the Institute ensured the construction of the most important railways of the country: St. Petersburg – Moscow, Transsib (Great Siberian Way), Turksib (Turkestan – Siberian Railway), Baikal – Amur Mainline (BAM), etc.; construction of subways in Moscow, Leningrad and other cities; the largest bridges, tunnels, canals, ports, hydroelectric power plants, creation of ground transportation infrastructure of Baikonur Cosmodrome, etc.

Emperor Alexander I St. Petersburg State Transport University (PGUPS); Saint Petersburg, Russian Federation

In the XX century the scientists of the Institute laid the foundations of scientific approach to the creation of aviation and automobile transport, introduction of electric and diesel locomotive traction on railways, advanced traffic control systems. Currently, scientists and specialists of the University are actively involved in the implementation of the largest infrastructure projects of the country: modernization of BAM and Transsib, development of the Moscow transport hub, creation of high-speed railways, construction of the Crimean Bridge, etc.

In 2021, as a result of a competitive selection process, the university entered the state program for the development of higher education organizations as part of the implementation of strategic academic leadership "Priority 2030".

For great merits in the development of transport and training of specialists the university was awarded the highest state awards of the USSR: the Order of Lenin (1945) and the Order of October Revolution (1984). In the structure of the university (2023): 2 institutes, 7 faculties, 13 branches, including 2 branches implementing programs of higher and secondary vocational education, 13 branches – secondary vocational education; library – the oldest (1809) and the largest, specializing in engineering and technical literature (more than 1.3 million items of storage, including the fund of rare books, manuscripts and drawings); museum; out-of-town geodesic base with scientific and educational railway training ground. Periodicals of the university: "Bulletin of St. Petersburg University of Railway Transport" (1884), magazine "Transport of the Russian Federation" (2005), "BRICS Transport" (2022) and others. The university has more than 20 thousand students (2023). PGUPS has wide and versatile international relations. More than 10 % of the contingent of students studying in higher education programs are foreigners.

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The Mission of the Emperor Alexander I Petersburg State Transport University

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ABSTRACT Emperor Alexander I St. Petersburg State Transport University is the only one of the universities subordinate to the Federal Agency for Railway Transport, which in 2021, among other 106 Russian universities, was awarded the basic part of the grant of the Priority 2030 program.

The Priority 2030 Program, approved by the Government of the Russian Federation, concentrates resources to ensure the contribution of Russian universities to achieving the national development goals of the Russian Federation for the period up to 2030. The program is aimed at increasing the scientific and educational potential of universities and scientific organizations, as well as ensuring the participation of educational organizations of higher education in the socio-economic development of the subjects of the Russian Federation.

Participation in this program opens up wide opportunities for import substitution and contributes to the university's going beyond solving urgent problems limited exclusively by the activities of railway transport.

During 2021–2022, Emperor Alexander I St. Petersburg State Transport University successfully implements all the projects outlined by the program and confidently reaches the goals it has set.

The article briefly describes the key tracks of the university's development during the implementation of the development program until 2030, as well as scientific and practical achievements obtained within the framework of strategic projects as of 2023.

KEYWORDS: higher education; transport; transport universities; import substitution; academic leadership "Priority 2030"

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Обзорная статья

Миссия Петербургского государственного университета путей сообщения императора Александра I

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АННОТАЦИЯ Петербургский государственный университет путей сообщения Императора Александра I (ПГУПС) – единственный из подведомственных Федеральному агентству железнодорожного транспорта вузов, который в 2021 г. в числе других 106 российских университетов был удостоен базовой части гранта программы "Приоритет 2030".

Программа "Приоритет 2030", утвержденная Правительством Российской Федерации, концентрирует ресурсы для обеспечения вклада российских университетов в достижение национальных целей развития РФ на период до 2030 г. Она направлена на повышение научно-образовательного потенциала университетов и научных организаций, обеспечение участия образовательных организаций высшего образования в социально-экономическом развитии субъектов РФ.

Участие в программе открывает широкие возможности для импортозамещения и способствует выходу вуза за пределы решения актуальных задач, ограниченных исключительно деятельностью железнодорожного транспорта.

На протяжении 2021–2022 гг. ПГУПС успешно выполняет все намеченные программой проекты и уверенно выходит на достижение намеченных ею целей.

Представлена краткая характеристика ключевых треков развития университета при реализации программы развития до 2030 г., а также научно-практические достижения, полученные в рамках стратегических проектов по состоянию на 2023 г.

КЛЮЧЕВЫЕ СЛОВА: университеты; транспорт; транспортное образование; импортозамещение; программа стратегического академического лидерства "Приоритет 2030"

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Emperor Alexander I St. Petersburg State Transport University (PGUPS) is the only university subordinate to the Federal Railway Transport Agency (Roszheldor), which in 2021 among other 106 Russian universities was awarded the basic part of the grant of the Priority 2030 program and included by the decision of the Minister of Science and Higher Education of the Russian Federation in the state program of strategic academic leadership "Priority 2030".

The university's participation in the Priority 2030 program is another confirmation of its high professional ambitions. The university development by 2030 is connected with the need to form an engineering vanguard to ensure Russia's intellectual sovereignty. This target image was formed and transformed taking into account the well-known events of the past years.

The strategic mission of the university to create fundamentally new engineering, technology and human capital development is relevant.

PGUPS realizes a matrix of policies, which are linked through strategic projects. Until this year, the university worked on four such projects: "Development of High-Speed Railway Service and Magnetolevitation Technologies", "Safe Transportation Ecosystem of Mainline Infrastructure", "Development of Transportation Infrastructure Facilities in the Arctic Zone of Russia", and "Digital Ecosystem of Intellectual Priorities for Transportation and Logistics".

Recognizing the changes in geopolitics and shifting agenda, PGUPS has revised the set of implemented strategic directions, clarified the vectors of development in all relevant areas. The University relies on the recommendations of experts of the operator of the largest state programs for the development of Russian universities, the Centre for Sociological Research (Sociocentre), proposed in 2022. Currently, PGUPS is implementing two strategic projects: "Safe Ecosystem of Intelligent Transport Infrastructure" and "New Technologies and Materials in Construction".

In order to consolidate the scientific potential and resources of PGUPS following the first, most difficult period of the Priority 2030 program implementation, PGUPS focused on two strategic areas useful for strengthening Russia's technological sovereignty in the "grocery shelf" format:

- development of digital solutions;
- creation of new materials.

A modern higher education institution is the country of tomorrow in terms of material, technical and laboratory facilities, innovative environment, support for young scientists, preservation of traditions of the best engineering education and accretion of industry values. Only the presence of all the above components will provide the university with a guaranteed qualitative evolution.

In research policy, the key result should be the increase in 2030 compared to 2020 of the volume of research and development (R&D) per one scientific and pedagogical employee by more than two times; the volume of expenditures on scientific development from own funds per one scientific and pedagogical employee by 19 times; the number of publications indexed in recognized science databases by more than two times.

The new challenges and demands of a volatile economy in an anti-globalization environment require from a modern university an appropriate response, which can and should be manifested in the unique characteristics of the main products of the university: knowledge, innovation and human capital.

In this regard, PGUPS has transformed the paradigm of further development in terms of protecting technological sovereignty, ensuring the sustainability of the university ecosystem in a volatile economy. The university relies on lean technologies that consistently realize continuous improvements relevant to the market. A lot of analytical work has been carried out, which resulted not only in reconfiguring strategic projects, but also in clarifying the functional role of partnerships on the actual ways of development of modern economy.

The mission of the university in the conditions of import substitution, localization of production within the country and accelerated formation of end-to-end technologies is the accumulation and implementation of new practices, breakthrough developments relevant for the development of a new technological mode. Taking into account the fact that for more than two hundred years PGUPS has been an advanced educational, research and production complex with a modern scientific and experimental base and acts as a growth point of national transportation education, science and innovation, it can be stated that the university has the necessary competencies.

Today scientists of PGUPS solve applied scientific and practical problems for the transportation industry of Saint Petersburg and the Russian Federation. The scientific infrastructure of the university is one of the largest in the country, based on the functioning of 17 leading scientific schools. The oldest of them are the schools of bridge and tunnel engineering, rolling stock, construction material science, automation and telemechanics, train traffic control, as well as railways of mainline, industrial and urban transportation.

The university has developed innovative technological solutions for the construction of fast-erecting buildings required for the sustainable development of Russian regions.

PGUPS scientists have patented a domestic environmentally friendly thermal insulation material, the use of which is oriented towards harsh climatic conditions.

In order to ensure the digital transformation of the transport industry, the university created a domestic end-to-end intellectual technology that allows organizing safe train traffic in automatic mode.

In 2022, PGUPS entered new markets that are beyond the typical markets of an industry-specific university. The range of research performed by the university has expanded: for the first time, most of the customers were not only Russian Railways, but also other representatives of real business.

The “Priority 2030” program also provides for the allocation of funds for the renovation of the laboratory research base for applied research in areas critical for the Russian Federation and relevant in the context of import substitution. The renewal process has already begun.

The university is keeping up with the times, four new laboratories have been put into operation in 2022 to perform relevant world-class research: the laboratory of digital modelling of high-speed railway construction; the training laboratory “Microprocessor and Electronic Telemechanical Devices of Railway Automation and Telemechanics”; geotechnical testing centre; and laboratory “Internet of Things”. They will make it possible to develop hardware and software complexes for operational deployment from domestic components, create innovative construction materials with unique characteristics, conduct expert examinations with the use of digital twins and tests of magnetolevitation transportation technology.

PGUPS meets the changes with fundamentally new competencies, breakthrough developments, new formats of education and academic cooperation, and innovative infrastructure.

The implementation of strategic projects, as the main drivers of the program, took place in accordance with the adopted roadmap. A distinctive feature was the integration of a number of projects within the framework of individual studies, conducted, among other things, at the new laboratory base.

The laboratory base is being actively developed, which allows the university to conduct R&D that meets the national goals of increasing railway capacity and Arctic transport development, implement new educational programs and offer products relevant to the challenges to Russia’s technological sovereignty.

The PGUPS development program is based on three pillars: new formats of cooperation, new models of education and implementation of a new pool of strategic projects.

During the period of participation in the program, the university has successfully implemented a model of ecosystem management of scientific and educational space, in which the vertical management is implemented by deputy heads of scientific direction appointed from among reputable scientists. The routes of the technological direction as a whole are determined by the scientific manager from production. The management horizon – for the head of educational programs from PGUPS and for the expert – the head of production – a top manager of a high-tech company. Training is based on flexible modules with “individual constructor” competencies. It is at their intersection that growth points are created and the skills of a unique specialist capable of managing the full life cycle of projects, innovations and high-tech production useful for the import substitution economy are formed.

Examples of successful achievements are a set of microprocessor systems based on microcomputers and programmable controllers developed by PGUPS scientists. All systems are based on domestic software and hardware technical solutions and cover the whole range of needs of mainline, industrial transport and subways in control of railway automation and telemechanics devices. More than 30 patents have been obtained and dozens of license agreements have been concluded. The geography of implementation of microprocessor-based centralization systems is extensive: more than 250 stations on the railways of Russia and 23 foreign countries, subways of six cities in Russia and CIS countries.

In 2022, PGUPS expanded the range of scientific research carried out on a customer-specific and turnkey basis. The university also performs R&D for business to meet the challenges of Industry 4.0, where priorities are set not only by customers, but also by the market.

PGUPS has long gone beyond the boundaries of an industry-specific university. A vivid example is the construction of a modern automated plant for the production of aerated concrete in Orenburg. This large-scale project was preceded by 10 years of scientific research of the university scientists on the development of structural and heat-insulating concrete. The new material is characterized by a unique combination of increased strength, operational reliability with improved heat and sound insulation properties, which has no analogues at present. The material possesses world novelty: 12 patents have been obtained on this topic and more than 70 scientific papers have been published. This complex project took into account both the customer's requirements and national priorities for localization of production within the country.

Speaking about the indicators of ongoing changes and transformation of the university within the framework of the Priority 2030 program, we can distinguish four groups of changes observed today.

1. Educational. This is the implementation of new educational programs and new competencies through the prism of project management. The indicator is the growth rate of the number of students.

2. Infrastructural. PGUPS creates its own hub of know-how from a number of new units for commercialization of scientific results. The indicator is the qualitative increase of comfortable labour and leisure spaces.

3. Research, because new topics of ambitious research meet national goals and require the development of new directions. And this is possible only in cooperation. Indicator – growth of the share of commercialization of scientific developments and the number of partners.

4. Creation of a team of young scientists to implement these changes. Today it includes 88 people, only full-time scientific and pedagogical staff. Indicator – the share of young employees aged under 39, working in the university.

The UNESCO report dated 04.03.2021 "Engineering for Sustainable Development" states that *"the training of engineers requires not only new professional qualities, including creative learning and thinking, complex problem solving, interdisciplinary and international cooperation and a code of ethics, but also requires changes in the training of the engineering profession itself"*. PGUPS is able to guarantee the knowledge-intensive development of transportation and stable supply of Industry 4.0 with human capital of a new formation.

Bionotes

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Railways of India. Time to update and upgrade

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ABSTRACT By the second decade of the XXI century, the railway transport of India came up with an important result — the Program announced on April 1, 1992, called Unigauge for the transfer of the railway network to a single gauge of 1676 mm was basically completed. In 2022, the operational length of wide-gauge roads on the Indian railway network was 65,094 km, or 95.7 % of its entire length. This opened up the possibility of creating a modern unified railway transport system and organizing its optimal interaction with other modes of transport.

The management of the railway transport of India, represented by the Ministry of Railways, has focused efforts on the modernization of all components of the large railway economy — strengthening track structures, upgrading bridge facilities, introducing modern means of ensuring train traffic and transportation safety, updating rolling stock. The basis for improving the work of railway transport is the electrification of railways, the completion of which is planned in the next decade.

All decisions taken to modernize railways are aimed at reducing operating costs, improving efficiency, environmental cleanliness, comfort and speed of passenger travel, reducing the delivery time of goods, as well as improving the safety of transportation by rail.

KEYWORDS: Indian Railways; history of transport; modernisation; electrification; increased economy and environmental friendliness of the transport; increased speed of freight and passenger delivery

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Обзорная статья

Железные дороги Индии: время обновления и модернизации

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АННОТАЦИЯ Ко второму десятилетию XXI столетия железнодорожный транспорт Индии подошел с важным результатом – в основном завершена объявленная 1 апреля 1992 г. Программа, получившей название Unigauge по переводу железнодорожной сети на единую колею 1676 мм. В 2022 г. на железнодорожной сети Индии эксплуатационная длина дорог широкой колеи составляла 65 094 км или 95,7 % всей ее протяженности. Это открыло возможность для создания современной единой транспортной системы железных дорог и организации ее оптимального взаимодействия с другими видами транспорта.

Министерства железных дорог Индии сосредоточило усилия на модернизации всех компонентов большого железнодорожного хозяйства – усилении конструкций пути, модернизации мостового хозяйства, внедрения современных средств обеспечения движения поездов и безопасности перевозок, обновления подвижного состава. В основу совершенствования работы железнодорожного транспорта положена электрификация железных дорог, завершение которой планируется в ближайшем десятилетии.

Все принимаемые решения по модернизации железных дорог направлены на снижение эксплуатационных расходов, повышение эффективности, экологической чистоты, комфорта и скорости проезда пассажиров, сокращение сроков доставки грузов, а также повышение безопасности перевозок по железным дорогам.

КЛЮЧЕВЫЕ СЛОВА: железные дороги Индии; история транспорта; модернизация; электрификация; повышение экономичности и экологической чистоты перевозок; увеличение скорости доставки грузов и пассажиров

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CURRENT STATE OF INDIA'S RAILWAY TRANSPORT AND PROSPECTS FOR ITS DEVELOPMENT

As noted earlier, India's state railways rank fourth in the world in terms of track length (68,193 km). Today, the Indian railway network is almost entirely on the 1676 mm wide gauge (95.7 per cent of the operational length). In terms of railway density – the number of kilometres of operational length per 1,000 km^2 of territory – India, compared to other countries, is in the middle of the list – 20.4 km/1,000 km^2, ahead of China (11.4) and four times higher than Russia (5.0). However, such an important indicator as the operational length of lines with two or more main tracks – 41.2 % of the total – needs to be improved. The relative indicator of the number of personnel engaged in railway operation is high; according to the given indicator per 1,000 km of operational length, it is 17.8 thousand persons (*Table 1*).

Indian Railways lags behind the other three largest railways in the world in terms of length: the US, China and Russia in terms of such an important indicator characterising transport output per unit length of the railway network as freight work per kilometre of operating length (freight load). The record holder in this indicator — Russian railways — has this value equal to 29.7 million tkm/km of operating length, while in China – 21.9; in the USA – 14.13; in India – 10.41 (*Table 1*).

The number of passengers carried in the first "Covid" year (2020) on Indian railways is 8086 million — is the highest in the world (in 2022, the number of passengers carried on Indian railways fell to 3,519 million), but if we look at it in comparison to the number of population, it is not that much. India has 17 times the population of Germany, but Indian railways carried only twice as many passengers as German railways in 2022.

However, the passenger intensity (passenger load factor) of Indian railways is high. With 8080 million passengers carried per year and 1 050 738 passenger kilometres travelled, it is 15.4 million passenger kilometres/km of operational length. In Japan, the figure is 9.7; in China, 8.62; in Germany, 1.38; in Russia, 0.8.

The British colonisers left an unenviable legacy to India in terms of technical equipment of railways. The main problem, as noted above, was the mainline railway network, which consisted of sections with different gauges. In 1955, out of 54,500 km of operational length, 25,17,000 km (or 46.1 per cent) were of 1676 mm gauge; 24,15,000 km (44.3 per cent) were of metre gauge and 5,200 km (9.85 per cent) were of narrow gauge (762 mm and 610 mm gauge lines)[1] [8]. A large amount of financial and material resources have been channelled by the Ministry of Railways of India over the past decades to unify the Indian railway network on the basis of 1676 mm wide gauge. By now, the objective has been practically achieved: of the 68,193 kilometres of operational length, 95.7 per cent are 1676 mm wide gauge railways.

In 1955, 8 years after the country's independence, the wide-gauge steel rails with the weight of 44.6–49.6 kg/run. m were laid on the main tracks, which made up 46.1 per cent of the operational length. The length of the laid track was small: from 9.14 to 12.8 m, which resulted in a large number of joints, required manual labour for maintenance, and did not allow to provide the necessary comfortable and safe movement of trains at a speed of more than 100 km/h according

[1] Data from the 1955 compilation of World Railways [9]; data published in 2023 by the Indian Ministry of Railways differ slightly from the above, but within 1–2 per cent. Project Unigauge.
URL: https://en.wikipedia.org/wiki/Project_Unigauge;
What is project unigauge. URL: https://www.railnewscenter.com/what-is-project-unigauge/railway-employee/

Table 1

Basic information on the railways of a number of technologically leading countries and BRICS countries

Country	Area, thousand km²	Population, million persons	Population density, persons/km²	Operating length, km	Of those with two or more tracks / % of total	Of those electrified / %	Average headcount of personnel, thousand persons	Number of personnel per 1000 km of track length	Density of operational railway length km/1000 km²	Passenger transport: Number of passengers, million persons	Passenger transport: Passenger operations, million passenger-km	Freight transport: Cargo transported, million tonnes	Freight transport: Freight operations, million tonnes-km	Residents per 1 km of track	Length of high-speed length[1], km: In operation	Length of high-speed length[1], km: Under construction	Length of high-speed length[1], km: To be planned
India[2]	3287	1425	420	*67 956* *68 043* 68 193*	25 034/36,8 *28 053/41,2*	39 329/57,9 *50 395/74,1*	1253,6 *1212,9*	18 462 *17 834*	20,6 *20,7*	8086,0 *3519,0*	1 050 738 *590 217*	1208,4 *1415,9*	707 665 *871 816*	20 969 *21 400*	–	508	7479
Brazil[3] 2019	8516**	213**	66**	29 817 (2008)	No data	Suburban only	No data	No data	3,3	867,7**	16 459**	No data	No data	7143**	–	–	Approx.** 500
China	9563	1411	148	109 767 112 072	77 114/70,2 *79 464/70,9*	88 417/80,5 *91 004/81,2*	1557,5 *1548,6*	14 197 *13 830*	11,4 *11,7*	2992,8 *1895,3*	946 499 *651 837*	2749,6 *2795,2*	2 404 180 *2 571 665*	12 800	40 474	13 063	11 238
France	549	67	123	27 213 *26 944*	11 200/41,1 *16 628/61,8*	16 013/58,8 *16 122/59,9*	124,4 *127,2*	4573 *5075*	45,5 *44,5*	879,6 *1131,8*	75 058 *100 814*	32,92 *31,0*	15 870 *15 869*	2462	2735		1725
Germany	358	83	233	33 399 *33 468*	18 556/55,70 *18 634/55,79*	20 540/61,6 *20 655/61,8*	323,6 *324,4*	9688 *9701*	93,2	1202,0 *1737,1*	46 169 *76 475*	226 *222,3*	84 850 *84 468*	2485	1571	147	291
Italy	301	59	197	17 305 *17 302*	7739/44,7 *7738/44,7*	12 208/70,5 *12 232/70,7*	85,8 *83,3*	4959 *4815*	57,4	865,1 *498,3*	34 169 *34 612*	No data	21 800 *21 971*	3409	921	327	
Japan[4]	378	126	333	15 621 19 123	5720/36,6	9689/62,1	111,4	7141	41,3	6610,9	151 711	No data	19 369	9218	3081	402	194
Russia	17 098	144	8	85 555	38 611/45,5	44 255/51,7	690,32	8073	5,0	872,0 *1135,0*	76 135 *122 762*	1366,4 *1355*	2 544 828 *2 636 555*	1683	659		670
South Africa	1219	58	47	20 953	12 955/61,1	7998/38,2	26,05 Partial data	1243	No data						–	–	–
Spain	506	47	94	15 963 *16 150* Partial data	6212/39,0 *6265/38,9*	10 345/65,0 *10 435/64,8*	28,58 Partial data	1367	31,5	403,8 *437,4*	16 821 *24 270*	15,88 *14,6*	5676 *5493*	2946	3661	1055	863
UK	244	67,2	276	16 351 *15 732*	10 101/61,9 *11 786/75,0*	6162/37,8 *642/38,4*	43,69 *42,0*	2680 *2670*	67,0	25,3 *3,3*[5]	8051[5]	33,2[6]	13 485[6]	4109	113	225	341
USA	9832	332	34	148 750 *148 553*	147 694/99,3 *148 553/100*	0 *0*	137,91	931	15,1	10,1 *24,4*	3593[7] *8232*	1260,1[8] *1333,7*	2 102 084[8)] *2 239 400,7*	2231	735	274	3784

Note: italics show UIC statistical data for 2022 [3, 4]; [1] – see [2]; [2] – in addition to UIC data [3, 4]; * – the operational length from Indian source [5] is given. [2]; [3] – in the UIC statistical report [3, 4] the data marked with ** are given. The rest of the data are from source [6]. After the mass privatisation of railways in Brazil between 1996 and 1999, intercity passenger traffic virtually ceased and is now carried by air transport and buses. Suburban railway traffic in the regions of Rio de Janeiro and São Paulo has been preserved; [4] – data for 2020 [3, 4]. Only the five largest railway companies within the Japan Railways Group (JRG) are reported, with no statistics for the smaller, mostly suburban, private companies. Information on track lengths of the West Japan Railway Company is not given. Data for the WJR Company's Sanyo Shinkansen line is taken from source [7]. JR Freight Company (JRF) does not have its own railway tracks, uses tracks of other companies and is not included in the statistics. In addition to UIC data, operating lengths are from a Japanese source [8]; [5] – data summarised for EUROSTAR INTL (2017) [3] and TRANSLINK (2018) [3, 4]; [6] – data for EUROSTAR INTL (2017) [3, 4]; [7] – data for Amtrak [3, 4]; [8] – data for Association of American Railroads [3, 4].

to the ideas of that time. The track was laid mainly on wooden sleepers, rarely on metal ones. On a number of narrow-gauge lines single cast-iron supports instead of sleepers were used [9, p. 359].

With such track structure maximum speeds on the wide track rarely reached 96 km/h, on the metre track — 72 km/h, on the narrow track 762 mm — 48 km/h and 610 mm — 29 km/h. On the electrified section of the wide-gauge passenger trains on several sections developed speed up to 104 km/h [9, p. 359].

At present, high-strength thermally compacted rails with the weight of 52–60 kg/run. m, welded into long lengths and laid on reinforced concrete sleepers with the help of elastic rail fasteners, are laid throughout the entire wide gauge railway network of India [10].

In 1955, the main means of communication in the movement of trains on especially important single-track sections was the electrical tablet system. The telegraph method of communication and such systems of train traffic organisation (mostly on metre and narrow-gauge lines, but also on some wide-gauge sections) as “movement by one locomotive”, “movement with one tablet”, “movement by written messages” were also used.

Autoblocking was used on some double-track lines and dispatch control of train traffic was introduced on a number of lines [9].

Single-wing semaphores were mainly used as signalling devices, signalling “track clear” by lowering the wing, as it is customary on the British railways. Traffic lights were used on autoblocked sections (about 100 km), as well as at a few large stations such as Bombay (Mumbai), Kolkata, and Madras, equipped with electrical centralisation systems for switches and signals. The Naihati sorting station is equipped with wagon retarders [8]. The Second Development Plan of Indian Railways (1956–1960) envisaged significant work to improve signalling, centralisation and interlocking (SCI) systems and to improve the safety of train traffic, however, until today the state of SCI and communication devices lags behind the general pace of development of the country’s railways.

As of the beginning of 2020, only 3.5 thousand kilometres of the operational length of railways have automatic interlocking of train traffic [10]. The rest of the length is mainly manually controlled by switches and signalling by signallers, mostly with the use of traffic lights. The development of signalling and communication systems with automatic devices, including the latest microprocessor-based ones, is the most important task of modernisation of Indian railways against the backdrop of one of the highest accident rates on Indian railways in the world today.

SWITCHING TO NEW TYPES OF TRACTION

In 1955 the main means of traction were steam locomotives, the total number of which was: 5,360 wide gauge, 2,789 metre gauge, 405 narrow gauge. There were 35 wide gauge diesel locomotives, 66 electric locomotives, two battery cars, 7 diesel locomotives of wide gauge, 46 of metre gauge, 151 of narrow gauge. On suburban electrified wide gauge sections 151 passenger motor cars were used, on electrified sections of metre gauge — 24 motor cars [9].

The total fleet of passenger cars was 8211 units (wide gauge), 6908 units (metre gauge), 1111 units (narrow gauge). The fleet of freight wagons included 157 thousand units (wide gauge), 59 thousand (metre gauge), 5.4 thousand (narrow gauge). Wide-gauge cars and partially metre gauge wagons were almost completely equipped with vacuum brakes, all narrow-gauge cars — with hand brakes [9].

Nowadays steam traction is used only for the movement of special excursion retro trains both on wide gauge and other railways. All passenger and freight work on the railway network is carried out using diesel locomotive and electric traction, which will be discussed in more detail below. New supplies of locomotives are made by Indian factories.

The freight wagon fleet is dominated by four-axle wagons for various purposes, the need for which will be met by Indian factories.

Indian railways are intensively renewing the passenger wagon fleet. Newly delivered passenger rolling stock of various purposes and comfort levels is mainly equipped with air conditioning systems, which is important for a country with a hot and humid climate.

The era of steam locomotives is considered to have ended on the Indian mainline railways on December 6,1985, when a steam locomotive of the WL-15005 series (*Fig. 1*) ran the last train on the gauge line from Ferozepur to Jalandhar, about 118 km. The production of steam locomotives in the country was completed even earlier. The last steam locomotive of the WG series was built at Chittaranjan Locomotive Works in June 1970 and was aptly named Antim Sitara — “The Last Star” in Hindi.

The first experiments with the use of diesel traction on Indian railways date back to the 1930s, when several small diesel locomotives with a capacity of about 300–1000 hp were operated on the North Western Railway on a trial basis — mainly for shunting work [11].

The first mainline diesel locomotives were put into operation on the Indian Railways after the country gained independence. These were diesel locomotives of the WDM-1 series[2] (*Fig. 2*), manufactured by the Ameri-

[2] Acronym WDM-1 from Wide Gauge (W); Diesel powered (D); Mixed load (M), the first model. One of these cars is preserved in the National Railway Museum in New Delhi.

Fig. 1. Steam locomotive series WL-15005 on the Rewari Steam Centre steam locomotive storage base[3]

Fig. 2. WDM-1 diesel locomotive No. 17000 at the National Railway Museum in New Delhi. 2020. Photo by Dmitry A. Shchukin[4]

Fig. 3. Diesel locomotive WDG-5. 2013. Photo by Chandra Vimlesh[5]

Fig. 4. Diesel locomotive WDG-6. 2020[6]

can Loco. Co. (ALCo) in 1957–1959 (the so-called "World Series of ALCo locomotives"). It was an electrically powered locomotive, having two bogies, each with three driving winding axles (UIC classification — axle formula C0–C0). Rated power of the 12-cylinder four-stroke diesel engine was 1,950 hp (1,450 kW), design speed was 104 km/h. The diesel locomotive had one control cabin (it was a section of "A" type) and could be operated as a combination of two sections coupled by the body ends without driver's cabins, with control by the system of many units to increase the power in train operation. A total of 100 such diesel locomotives were purchased.

At present, the Indian industry produces diesel locomotives for various purposes for operation on wide gauge and shunting mainline railways, as well as metre gauge and narrow-gauge diesel locomotives.

In the last decade two models of powerful diesel locomotives with electric transmission for freight work WDG-5 and WDG-6 have been produced in India. The WDG-5 diesel locomotive (*Fig. 3*), built by Banaras Locomotive Works (BLW) in Varanasi in collaboration with Electro-Motive Diesel (the diesel locomotive and electric locomotive division of Caterpillar Inc.), has a hood type body, C0 to C0 axle arrangement. Nominal diesel power is 5,500 hp (4,045 kW). In 2012–2018, 7 WDG-5 locomotives were manufactured.

The WDG-6 electric diesel locomotive (*Fig. 4*) also, like the one mentioned earlier, has a bonnet type body and the same C0 to C0 axial formula. The first two vehicles were produced at the former GE Rai, now Wabtec plant of Westinghouse Air Brake Technologies Corporation and MotivePower Industries' Westinghouse Air Brake Technologies Corporation in the US and delivered to India in 2019.Production of these diesel locomotives was then organised at General Electric India's plant in Marhaura, Bihar.

The WDG-6 freight diesel locomotive with a design speed of 100 km/h is designed based on the GE Evolution Series platform and is powered by a four-stroke 16-cylinder supercharged four-cylinder diesel engine with a rated power of 6,000 hp (4,416 kW). With an axle load of 23 tonnes, this diesel locomotive is one of the most powerful in the relatively lightweight category in the world.

ELECTRIFICATION OF THE INDIAN RAILWAYS

Electrification is the most important area of railway infrastructure improvement in India, in addition

[3] Development of Steam Locomotive Designs in Railways in India // URL: https://artsandculture.google.com/story/2AVhj-uITVuVKA
[4] URL: https://railgallery.ru/photo/41545/?vid=102920
[5] URL: https://www.flickr.com/photos/67259157@N06/9333137336
[6] URL: https://d.indiarailinfo.com/loco/26100

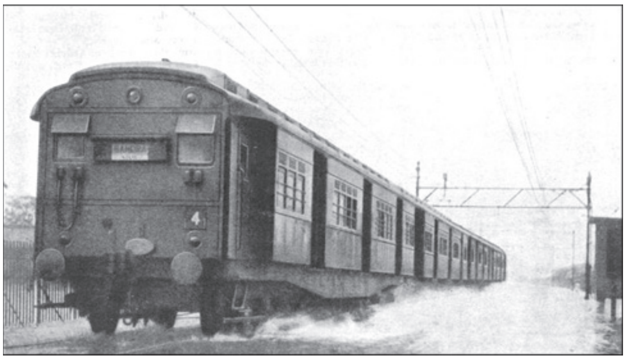

Fig. 5. An electric train on the Victoria Terminus line in Bombay (today Chhatrapati Shivaji Terminus and Bandra station on the outskirts of Bombay (Mumbai). The train is travelling on tracks flooded by monsoon rains. Mid-1920s[7]

to bringing the entire railway network to a single track. The first proposals for the use of electric traction were presented in India in 1925 and the budget for the initial work was set at the same time [12]. As in many countries, railway electrification in India started with small suburban sections. On March 3, 1925, a 1.5 kV DC electrified (with power from the overhead catenary) section between Victoria Terminus in Bombay (now Chhatrapati Shivaji Terminus in Mumbai) and Bandra suburban station on the Arabian Sea coast (now called Harbour Line) was put into operation.

The electrification was based on technical solutions well proven on the Newport-Shildon, England line, which were among the most advanced at the time. Electric trains were supplied by Kamele Laird (England) and Uerdingenwagonfabrics (Germany) [12, 13]. The electrical components for these trains (*Fig. 5*) were supplied by BTH/AEI and English Electric from England, Siemens-Schuckert from Germany, and Ansaldo from Italy.

Electrification on the main lines using 1.5 kV direct current began with the modernisation in 1929–1930 of the high gradient sections in the Western Ghats on the busy Great Indian Peninsula Railways (GIP) freight and passenger main line. Here the operation of the powerful EF/1 series of electric freight locomotives began, the first of which arrived at the port of Bombay in August 1927.

These articulated locomotives were typically German-Swiss in design and appearance and had coupled wheels with drawbar gearing, resembling that of a steam locomotive, from two mono-electric motors mounted on the frames of the two end bogies. The electric motors were placed on the frame of the locomotive, as in the famous Swiss articulated electric locomotive Ve 6/8 series, nicknamed “Crocodile” for its characteristic profile resembling a toothy reptile. This locomotive proved itself in train work on the Gotthard Pass in the Alps. In India, these electric locomotives with a power of 1940 kW and a design speed of 80 km/h also came to be called “Crocodile”. Later, the Indian Railways changed their EF/1 series name to WCG-1[8] (*Fig. 6*).

Following the British tradition of naming locomotives like ships after prominent figures, the first of the EF/1 (WCG-1) locomotives to arrive was named Sir Leslie Wilson[9].

On 1 June 1930, the Deccan Queen high-speed passenger train was put into service[10], which established itself as one of the most luxurious trains of its time, not only in India but also in the world (*Fig. 7*). The train

Fig. 6. WCG-1 series electric locomotive commissioned in 1930 and decommissioned in 2020 at the National Railway Museum, New Delhi. 2020[11]

[7] Electrification overseas. Development of Power Schemes in the Dominions. URL: http://mikes.railhistory.railfan.net/r099.html
[8] WCG-1 – acronym for wide gauge (W); direct current (C) – this is how direct current was agreed to be labelled, as opposed to Alternating Current (A); Goods traffic (G). Two of these locomotives have been preserved to this day.
[9] Sir Leslie Orme Wilson (1876–1955) is a participant of the Second Anglo-Boer War, captain of the Royal Marines, participant of the First World War with the rank of colonel, prominent British politician, member of the British Parliament, from 1923 Governor of Bombay, supported and promoted the idea of electrification of the Indian railways, from 1832 to 1946 (the longest in this position) – Governor of Queensland in Australia.
[10] The name of the train is derived from the vernacular respectful name of the city of Pune “दख्खन ची राणी” Deccan Queen, the cultural capital of the region. The city is located in the historical and socio-political region known as Deccan, occupying a mountain plateau of the same name, stretching a little south of Mumbai from the coast of the Arabian Sea to the Bay of Bengal.
[11] URL: https://www.tripadvisor.com/LocationPhotoDirectLink-g304554-d19799017-i443857282-Heritage_Gully-Mumbai_Maharashtra.html

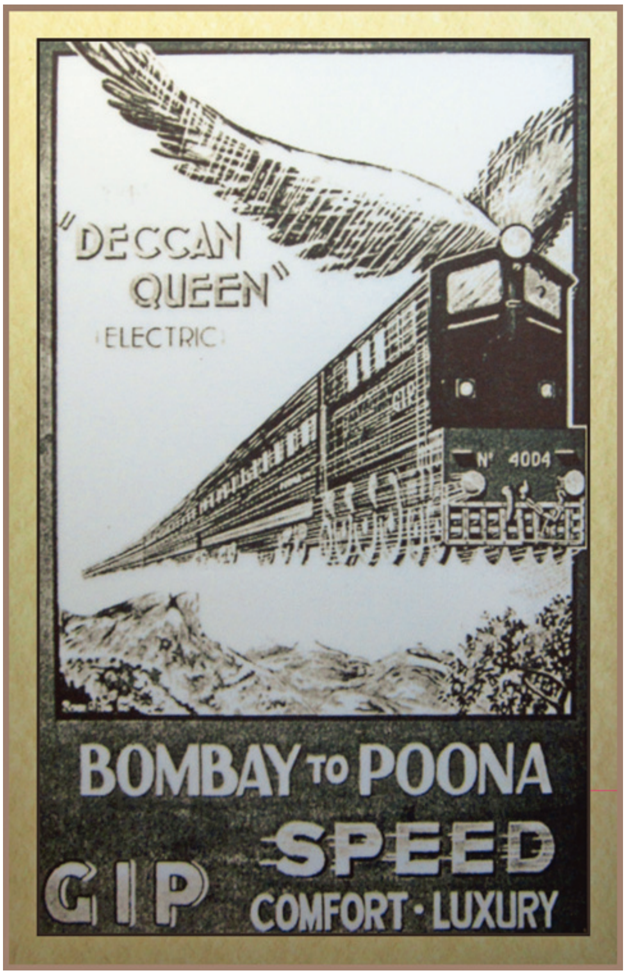

Fig. 7. An advertising poster from the early 1930s of the Deccan Queen, a posh Indian express train of its time. Chhatrapati Shivaji Terminus Museum, Mumbai. Photo by the authors. 2016

was designed for wealthy passengers travelling from Bombay (Mumbai) to the city of Pune[11] (Poona) [14], where horse races were held at the nationally famous hippodrome, attracting the socialite public. The train was initially timetabled on weekends, but later became a daily service. This very popular express train was a first in India: the long-distance train was served by electric locomotives, and for the first time in India its carriages were connected by enclosed crossing platforms[12] (so-called {vestibuled trains}, for the first time special carriages for women and a dining carriage were included in the composition of the train.

The train covered a distance of 192 kilometres between end points in 4 hours (today — 3 hours 10–15 minutes) with a route speed of 50 km/h, reaching speeds of 80 km/h in some sections (up to 105 km/h today).

The services provided to passengers en route, the comfort and convenience of the train carriages, and, most importantly, the speed of the journey, have brought the train the love of wealthy passengers over the ninety years of its operation. The Deccan Queen train's birthday is celebrated every year on June 1 as a celebration of the Deccan region.

The Deccan Queen trains were served by India's first passenger high-speed electric locomotives, the EA/2, later renamed WCP-2, a 1.5 kV DC 1,562 kW locomotive with a design speed of 137 kilometres per hour. This Swiss Locomotive and Machine Works (SLM) designed electric locomotive was one of the most successful high-speed locomotives of its time. The first car was named Sir Roger Lumley[13] (*Fig. 8*).

Before India's independence in 1925–1947, only 388 km of railways were electrified [14]. Under the 1951–1956 plan, another 141 km were electrified.

In 1958, electrification was carried out in the Howrah – Bardhaman section of the Eastern Railway in the form of an experiment using DC of higher voltage — 3kV.

Fig. 8. The Sir Roger Lumley electric locomotive, commissioned in 1930, was the first passenger electric locomotive of the Indian Railways. A 1.5 kV DC, type 1-2-2 machine, originally given the serial name EA/2, later renamed WCP-2, preserved in the National Railway Museum, New Delhi. It is believed that this particular electric locomotive was part of the first Deccan Queen train to enter the route on June 1, 1930[14]

[12] Prior to this, all passenger coaches in India had open inter-carriage platforms, which were uncomfortable and dangerous to use when travelling from carriage to carriage. The introduction of enclosed vestibule platforms between carriages by the American company Pullman in 1887 for the first time united the carriages of a passenger train into a single comfortable space and gave rise to the creation of Pullman luxury trains — "palaces on wheels". In 1930, the first such train appeared in India.

[13] Lawrence Roger Lumley, 11th Earl of Scarbrough (1896–1969) — politician, General of the British Army, member of the House of Commons of the British Parliament, Governor of Bombay, Chancellor of Durham University.

[14] URL: https://www.irfca.org/gallery/Heritage/img113.jpg.html

In 1957 the leadership of the country and the railways made an important decision on further electrification of the railways only on the system of alternating current of 50 Hz industrial frequency with voltage of 25 kV. In 1960, the first pilot section of the South Eastern Railway Raj Kharswan – Dongoaposi was electrified. Since then, electrification in India has been carried out only using 50 Hz industrial frequency alternating current [10, 11].

In 1961, India started its own production of WCM-5 electric locomotives. Before that, all electric locomotives were delivered from abroad in a fully assembled form. The creation of its own electric locomotive manufacturing was a great achievement of the country in the process of gaining technological sovereignty. The first WCM-5 was a DC electric locomotive with DC traction collector motors with a total power of 2721 kW and a design speed of 105 kilometres per hour. The first electric locomotive was given No. 20083 and the name Lokmanya[15] (*Fig. 9*). The locomotive was assembled on October 14, 1961 at the Chittaranjan Locomotive Works, a locomotive and steel works established in 1950. India's first Prime Minister Jawaharlal Nehru attended the launching ceremony of the locomotive. It is believed that this locomotive later drove the famous Deccan Queen express train.

At present, the Indian industry produces modern electric locomotives for various purposes, including freight traffic. One of the most powerful in the world two-section eight-axle freight locomotive of WAG-12B series was created by Indian specialists at Electric Locomotive Factory, with the support of French concern Alstom. The AC locomotive with asynchronous three-phase motors with a total power of 8820 kW and a design speed of 120 km/h is designed for use on freight lines to drive trains weighing more than 6000 tonnes. The electric locomotive is equipped with four Alstom-designed traction converters on GTO and IGBT semiconductor elements.

The first WAG-12B electric locomotive was ceremonially released from the plant on 10 April 2018 with the participation of Indian Prime Minister Narendra Damodardas Modi (*Fig. 10*). On April 3, 2023, the 300th locomotive of this series was handed over to Indian Railways for service.

Among the expected new additions to Indian Railways' high-speed rail passenger electric rolling stock

Fig. 9. WCM-5 series electric locomotive No.20103, kept at the National Railway Museum in New Delhi. Photo by Basu Avishek[16]

Fig. 9. WCM-5 electric locomotive No. 20083 Lokmanya leads the Deccan Queen express. July 1980. Photo by Vaedhal Harsh[17]

Fig. 10. Electric locomotive WAG-12B with goods train 2020[18]

[15] Lokmanya Bal Gangadhar Tilak (1856–1920), marāṭhī, Indian politician, nationalist, conservative, advocate of orthodox Hinduism and fighter for Indian independence, the first leader of the Indian independence movement, nicknamed "Lokmanya" by the people, meaning "accepted by the people as a leader", persecuted by the British colonial authorities, imprisoned for several years. Mahatma Gandhi called him "the creator of modern India".

[16] URL: https://24coaches.com/the-electric-locomotive-roster-dc-acdc-electrics/

[17] URL: https://www.irfca.org/gallery/Locos/Electric/wcm1_to_6/img097.jpg.html?g2_imageViewsIndex=1

[18] URL: https://www.rushlane.com/indias-most-powerful-train-engine-first-official-video-12362674.html

are the Vande Bharat electric trains, which were previously available in the seating version. According to media reports, an agreement has been signed in New Delhi to set up a new company, Kinet Railway Solutions, which will supply 16 long-distance coach trains with sleeper seats to Indian railways. The joint venture with the participation of JSC Transmashholding (TMH, 75 per cent share) and the Indian company Rail Vikas Nigam (25 per cent) will build Vande Bharat trains and provide their service. It will manufacture 120 long-distance electric trains based on the results of a tender organised by Indian Railways, the results of which were announced on March 1, 2023 [16].

CHANGE IN THE STRUCTURE OF THE TRACTION ROLLING STOCK FLEET

Back in the 1990s, several thousand steam locomotives were in operation in the country; today about three dozen steam locomotives are used only for driving tourist vintage trains. Initially, the fleet of diesel locomotives increased rapidly with the beginning of work on replacing steam traction with progressive — diesel and electric traction. In 1990–1991, the number of diesel locomotives exceeded the number of electric locomotives, but in the 2000s, as electrification rates increased, the growth of diesel locomotives slowed down and stopped by 2010. At present, the number of electric locomotives in train operations is one and a half times that of diesel locomotives. Electric locomotives carry about two-thirds of freight traffic in India. Approximately 60 % of passenger trains run on electrified IR lines, and they account for 38 % of the total electricity expenditure on traction [17]. *Table 2* shows how the composition of the locomotive fleet of Indian railways has changed (based on data up to 31 March 2021), *Table 3* shows the change in the share of different types of traction in the volume of train operations in passenger and freight traffic [17].

As of the end of 2022, 52,500 km of railways in India have been electrified, accounting for 77.1 % of the total operational length (*Table 4*) [15]. In FY 2021, India has achieved the longest electrification in all the years of such work — 6015 km. In the last seven years

Table 2

Change in the structure of the locomotive fleet

Years	Number of locomotives, units			
	Locomotives	Diesel locomotives	Electric locomotives	Total
1950/1951	8,120	17	72	8,209
1960/1961	10,312	181	131	10,624
1970/1971	9,387	1,169	602	11,158
1980/1981	7,469	2,403	1,036	10,908
1990/1991	2,915	3,759	1,743	8,417
2000/2001	54	4,702	2,810	7,566
2010/2011	43	5,137	4,033	9,213
2020/2021	39	5,108	7,587	12,734

Table 3

Share of different types of traction in the volume of train operations, %

Years	Passenger traffic				Freight traffic		
	Locomotives	Diesel locomotives	Electric locomotives	Electrical train	Locomotives	Diesel locomotives	Electric locomotives
1950/1951	93.0	–	2.0	5.0	99.0	–	1.0
1960/1961	91.0	–	2.0	7.0	94.0	5.0	1.0
1970/1971	77.0	7.0	7.0	9.0	46.0	39.0	15.0
1980/1981	49.0	25.0	14.0	12.0	18.0	62.0	20.0
1990/1991	21.8	42.4	22.6	13.2	3.0	60.6	34.4
2000/2001	–	56.2	31.2	12.7	–	43.5	56.5
2010/2011	–	49.4	36.6	13.9	–	37.5	62.7
2020/2021	–	18.8	63.7	17.4	–	27.0	73.0

Table 4

Length of electrified tracks

1951	388
1961	748
1971	3,706
1981	5,345
1991	9,968
2001	14,856
2011	19,607
2021	44,802
2022	52,508

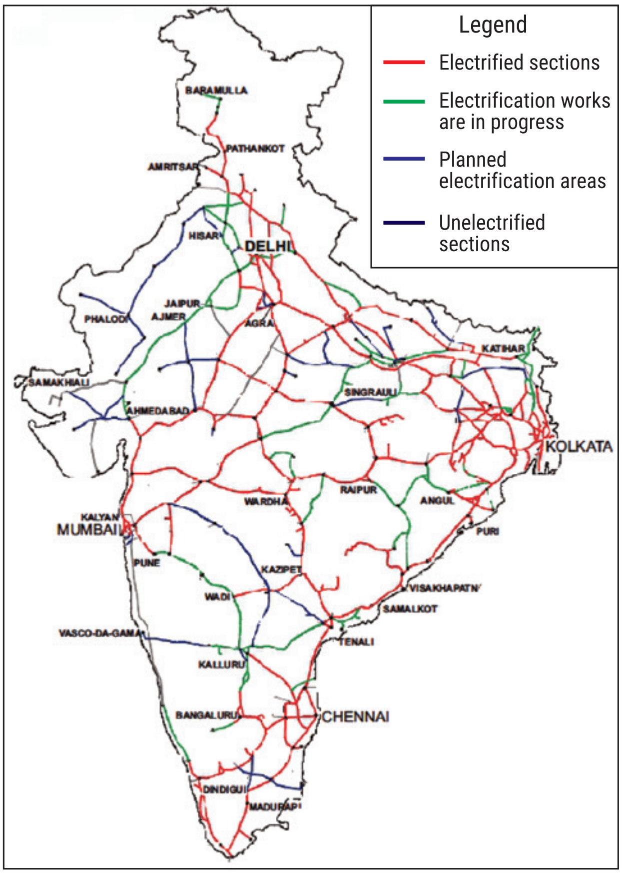

Fig. 11. Prospective scheme for electrification of India's railways. 2015[19]

(2014–2021), the electrification rate has increased more than 5 times compared to 2007–2014 (*Fig. 11*). It is planned that by 2024, Indian railways will be almost completely converted to electric traction [5].

PROSPECTS FOR THE DEVELOPMENT OF THE INDIAN RAILWAYS

Over the years, a forward-looking railway development plan has been evolving with the participation of various organisations in the country under the leadership of the Ministry of Railways of India. On March 21 2022, the Ministry of Railways published the National Railway Plan of India (NRP), which aims to create a future-ready railway system by "2030" [18]. India's National Rail Plan 2030 aims to create a greener and cheaper to operate network of accessible and efficient railways.

The plan aims to reduce freight delivery time by increasing the average speed of goods trains to 50 km/h. The new plan aims to reform and make the railways more sustainable, efficient and modern, while providing cheaper safe passenger and freight transport.

In a written reply to an enquiry by the Rajya Sabha Constitutional Council of States, India's Minister of Railways, Communications, Electronic & Information Technology Ashwini Vaishnaw said {Minister of Railways, Communications and Electronic & Information Technology Ashwini Vaishnaw}: "The objective of the Plan is to build capacity ahead of demand, which in turn will also contribute to future demand growth up to 2050 and also increase the share of railways in freight transport to 45 %. To achieve this goal, all possible financial models are being considered, including public-private partnerships (PPPs)" [19].

Other important objectives of the NRP include identifying new high-speed rail corridors and new dedicated freight corridors, estimating rolling stock requirements for passenger traffic, and freight wagon and locomotive requirements to meet the goals of 100 % electrification and increased freight share.

In addition, the new plan aims to ensure sustainable private sector participation in various areas such as freight and passenger terminal development, rolling stock operation and ownership, and track infrastructure development and operation.

Under the Vision 2024 NRP, measures have been taken to accelerate some critical projects including construction of second and third tracks on congested routes and 100 % electrification [18, 19].

The priorities for 2030 include: updating the technical policy and regulatory framework of Indian Railways; introducing effective means to improve the efficiency and safety of Indian Railways; a strategy to attract private capital to the railways; and infrastructure development [18].

CONCLUSION

Over the last two decades, after solving the urgent task of uniting the country's railway network on the basis of reconstruction of the most important transport directions with a single 1676 mm gauge, the Indian railway transport has started technical re-equipment of the industry on the basis of introduction of electric traction. The initial stage of replacing steam traction with diesel locomotive traction, which was carried out in the 1970s and 1980s, was replaced in the 1990s by the active introduction of electric traction against the background of the unprecedented electrification of the country. Indian railwaymen took as an example the model of railway development in the USSR-Russia and China, rejecting the Ameri-

[19] Indian railways green energy initiatives. URL: http://www.irgreenri.gov.in/tile_elect.html

can way of railway development — the use of diesel traction as environmentally harmful and dead-end for the country, which needs huge volumes of liquid hydrocarbon fuel, which has to be imported from abroad.

The Indian railways are faced with the challenge of improving control systems and train safety to make full use of the upgraded track facilities, the benefits of electric traction in increasing the speed of transport and the safety of rail transport.

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Technical and legal regulation of urban railways

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ABSTRACT The article deals with the issues of legal and technical regulation of railway transport infrastructure facilities in cities and urban agglomerations. An attempt was made to determine the legal status of such objects. The features of such railways are considered, the need for highlighting regulation of urban railways is indicated. It is proposed to initiate work on establishing the priority of passenger transportation over freight in the territory of cities and urban agglomerations.

Possible ways to solve the stated problem are proposed, consisting in several measures, including the definition of a list of regulatory documents that prevent the allocation of a separate regulation of railway transport in cities and urban agglomerations, conducting relevant scientific research and preparing proposals for amending regulatory documents.

KEYWORDS: legal regulation; technical regulation; urban railways

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Научная статья

Нормативно-техническое и нормативно-правовое регулирование городских железных дорог

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АННОТАЦИЯ Рассмотрены вопросы нормативно-правового и нормативно-технического регулирования объектов инфраструктуры железнодорожного транспорта на территории городов и городских агломераций. Сделана попытка определить правовой статус данных объектов. Приведены особенности таких дорог, указана необходимость выделения нормативного регулирования городских железных дорог. Предложено инициировать работу над установлением приоритета пассажирских перевозок над грузовыми на территории городов и городских агломераций.

Представлены возможные пути решения проблемы, заключающиеся в ряде мероприятий, включающих определение перечня нормативных документов, препятствующих выделению отдельного регулирования железнодорожного транспорта на территории городов и городских агломераций; проведение соответствующих научных исследований и подготовки предложений по внесению изменений в нормативные документы.

КЛЮЧЕВЫЕ СЛОВА: нормативно-правовое регулирование; нормативно-техническое регулирование; городские железные дороги

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INTRODUCTION

The growth of cities and urban agglomerations entails the development of their transportation network. Often, public transportation resources are limited and metro construction is expensive.

Most cities and urban agglomerations of the Russian Federation are also large railway hubs with an extensive network of railway stations and crossings, which, using international experience, can be organically integrated into the public transport system. The experience of Moscow agglomeration, which has been successfully operating the railway network of Moscow transportation hub for several years, is considered advanced in our country.

However, there is a large list of problems that limit the use of this resource in cities and urban agglomerations. These problems are of both regulatory and normative-legal and regulatory-technical nature.

This article is devoted to analysing these problems and trying to find ways to solve them in the regulatory and legal field of the Russian Federation.

SPECIFIC FEATURES OF TECHNICAL AND LEGAL REGULATION OF URBAN RAILWAYS IN THE RUSSIAN FEDERATION

Currently, the design, construction, reconstruction and operation of public railway transportation infrastructure facilities are carried out in accordance with a number of regulatory and technical documents of the Russian Federation.

Federal Law "On Railway Transportation in the Russian Federation"[1] says that *"railway transport in the Russian Federation consists of public railway transport, non-use railway transport, as well as technological railway transport of organizations..."*

Part two of Article 14 of the Law[1] establishes that access to infrastructure is provided to carriers on a non-discriminatory basis, providing for equal conditions for the provision of services for the use of infrastructure by carriers regardless of their incorporation forms and forms of ownership.

The legislation of the Russian Federation defines access to the railway transportation infrastructure regardless of the location of a given railway: within the urban agglomeration or outside its boundaries. This means that the legal status of the urban railway in the Russian Federation is not separately identified.

In 2017, the Federal Law "On Off-Street Transportation" was adopted, but its wording was criticized by scientists and specialists in this field [1].

The current system of technical and legal regulation of public railway transport infrastructure facilities, as well as related processes mentioned above, lacks the specifics of such regulation for the railway transport of cities and agglomerations.

THE NEED TO EMPHASIZE THE LEGAL REGULATION OF URBAN RAILWAYS

The need to highlight the legal and technical regulation of the railway transportation of cities and agglomerations is long overdue. To date, there have been many studies on this issue [2–8].

Here are the main reasons for such a separation, according to the authors of the article.

1. One needs to prioritize meeting the needs of the population in passenger transportation within cities and urban agglomerations over freight transportation. For example, in the Moscow agglomeration such a priority has already been established on the Moscow Central Ring and Moscow Central Diameters. However, in other urban agglomerations, such as Saint Petersburg, it has not yet been implemented. Freight trains, including those with increased weight and length, operate in almost all directions.

Until this important problem, which lies in the regulatory and legal plane, rather than in the technical, is solved, further talk about the development of urban railways in the Russian Federation is premature.

2. Urban agglomerations are characterized by constraints in the design of new railway lines, additional main tracks, reconstruction of existing railway lines and railway stations. There are planning constraints associated with the existing development that do not allow fitting the route parameters required by standardization documents (codes of rules and standards), which are now defined for mainline railways. This may also include dense saturation of underground space with utilities, the requirements for protection or removal of which from the construction site also impose restrictions.

All of the above restrictions derive from the original intent of the Federal Law "On Railway Transport", which defines non-discriminatory access for carriers. At present, there are no restrictions for the owner of the railway transportation infrastructure on the movement on urban railways, for example, of loaded trains with a length of 71 conventional cars or coupled trains. Technical regulation of the processes of design, construction, reconstruction and operation of urban railways is difficult for this reason.

3. It should be noted that there are special conditions for the operation of railway transport infrastructure fa-

[1] Federal Law dated 10.01.2003 No.17-FZ "On Railway Transport in the Russian Federation" (as amended on 29.12.2022).

cilities that ensure the priority of passenger transportation (including axle loads, train speeds, train lengths, train intervals, etc.) over mixed or freight traffic.

Such factors refer to:

- lower axle loads compared to freight cars and more advanced design of running parts of passenger rolling stock, which have less force impact on the railway track, which allows both optimizing the design of the railway track and reducing the requirements for the protection of underground utilities;
- possibility of reducing the radii of curves due to the exclusion of mainline locomotives, which cannot fit into curves of small radii, as well as reducing the distance of approaching structures due to the admission of only specialized passenger rolling stock to the urban railway, which will reduce the cost of construction or reconstruction in dense urban areas;
- the need to introduce clock traffic, increase train speeds, train interval, which imposes special conditions on the reliability of subsystems of railway automation and telemechanics, railway power supply and railway telecommunications;
- requirements for vibration and noise reduction and other environmental requirements affecting nearby residential development;
- other factors.

One needs to find a comprehensive solution to this problem, including a combination of solutions at the level of the legislative and executive branches of government, as well as the development of standardization documents and infrastructure and business owner decisions.

POSSIBLE SOLUTIONS

A comprehensive approach to solving this problem, proposed by the authors, is based on the establishment at the federal level of the priority of passenger transportation over freight and mixed transportation in the territories of cities and urban agglomerations, ensuring a comfortable and accessible environment for citizens.

This problem can be solved through a comprehensive public discussion of the issue of prioritizing passenger transportation in the territories of cities and urban agglomerations; amendments to the main federal laws regulating these issues.

It is required to amend or develop new regulatory legal acts of various levels (federal laws, resolutions of the Government of the Russian Federation, orders of federal executive authorities), as well as standardization documents (national and interstate standards and sets of rules) in conjunction with existing regulatory documents.

At the initial stage the following tasks should be solved:

1. To determine a complete list of regulatory legal acts governing the activities of railway transportation. To determine the provisions of such regulatory legal acts that prevent the allocation of a separate regulatory framework for railway transportation in the territory of cities and agglomerations.

2. To prepare proposals for amendments to the regulatory legal acts that would allow for such regulation.

3. To initiate research and development work confirming the possibility of changing the technical requirements for railway transportation infrastructure facilities of cities and urban agglomerations, which will ensure the safety requirements established by technical regulations.

4. On the basis of the research work performed, initiate amendments or the development of new standardization documents to ensure the design, construction, reconstruction and operation of railways in cities and urban agglomerations in accordance with the system of developed and approved regulatory legal acts.

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The use of numerical simulation in the analysis of aerodynamic problems in transport

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ABSTRACT The study of the aerodynamic impact of rolling stock on the railway infrastructure is carried out either with experimental methods or with numerical simulation methods. The use of numerical simulation methods allows you to safely and quickly obtain the necessary data. An important task is to determine the factors that affect the aerodynamics of the rolling stock. To study aerodynamic processes in transport it is proposed to use the Frozen Rotor method in combination with the Large Eddy Simulation, which can be implemented using the Solid Works Flow Simulation software package. This method makes it possible to obtain a high-quality picture of the distribution of air flows in the boundary and main layers.

KEYWORDS: finite volume method; numerical simulation; aeroelastic interaction; turbulence; Frozen Rotor method

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Научная статья

Использование численного моделирования при анализе аэродинамических проблем на транспорте

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АННОТАЦИЯ Исследование аэродинамического воздействия подвижного состава (ПС) на железнодорожную инфраструктуру осуществляется с помощью экспериментальных методов или методов численного моделирования. Использование методов численного моделирования позволяет безопасно и быстро получить необходимые данные. Важной задачей является определение факторов, которые влияют на аэродинамику ПС. Для исследования аэродинамических процессов на транспорте предлагается применить метод Frozen Rotor в комбинации с методом крупных вихрей, что можно реализовать с помощью программного комплекса SolidWorks Flow Simulation. Применение данного метода дает возможность получить качественную картину распределения воздушных потоков в пограничном и основном слоях.

КЛЮЧЕВЫЕ СЛОВА: метод конечных объемов; численное моделирование; аэроупругое взаимодействие; турбулентность; метод Frozen Rotor

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INTRODUCTION

To solve problems related to the aerodynamic interaction of rolling stock (RS) with the railway infrastructure, an experimental method (full-scale) or a numerical simulation method using specialized software is used.

The experimental method is often difficult to use. And when analyzing the aeroelastic interaction of rolling stock with tunnel structures, it may be impossible to apply it due to the following factors[1]:

1. High cost and technical complexity of installing air pressure sensors on tunnel walls without interrupting train traffic.

2. Speed measurements are life-threatening because they require being close to a moving train. 3.

3. Insufficient objectivity of research results due to the presence of many limiting factors that do not allow placing the equipment properly.

One of the most realistic experimental methods is blowing a model train in a wind tunnel. But it is not universal because it is costly, numerical results of flow distribution are difficult to interpret.

The use of numerical modelling of aerodynamic processes makes it possible to overcome these difficulties. Modern computer programs, in which the finite element method and solid modelling of infrastructure objects are applied, allow solving a wide range of problems related to the interrelated stationary and non-stationary thermal and aerodynamic fields and processes in tunnel structures during the movement of the train station.

SPECIFICS OF APPLICATION OF NUMERICAL METHODS

Experimental values are required to verify the computer model in any case. With this option, there is no need to investigate many cases; one case is sufficient. If the model proves to be adequate, other cases can be numerically simulated by interpreting the base values using various mathematical methods.

In numerical modelling using the finite volume method, it is important to set the boundary conditions correctly to simulate the interaction of the gas with moving and stationary walls, as well as the effects of the environment. When the air medium interacts with moving surfaces, the surfaces are deformed, which requires the solution of the Navier – Stokes and Laplace equations to account for the stress-strain state of the surfaces [1].

The solution of the problem by the finite volume method in such a formulation requires considerable computational resources. However, in the case of aeroelastic interaction between the rolling stock and artificial structures, the deformations of the surfaces are small; therefore, assumptions are made that there is no change in the shape of the interacting surfaces at all velocities of the rolling stock motion. For wall modeling, the velocity component normal to the surface is assumed to be zero, which means that the solid wall is impermeable. There is no slippage of the medium along the wall. The stationary moving walls of the computational domain are assumed to be smooth. Such assumptions allow us to reduce computational costs and maintain the correctness of the obtained data [2, 3].

Due to the presence of viscous friction forces near the surface of the streamlined body, the flow velocity changes and a boundary layer appears. In this case, at the surface of the body, the flow velocity is equal to the body velocity, and as the body is removed, there is a gradual change in the flow velocity from the body velocity to the velocity of the external flow streamlined around the body.

The flow around the surface of the body of the rolling stock can be divided into two layers: the boundary layer, in which there is a relative movement of air layers, and hence the viscous (friction) forces perceived by the body of the train, and the main flow moving at a constant speed, in the volume of which the forces of viscous friction manifest themselves insignificantly (*Fig. 1*).

Friction forces in the boundary layer create frontal resistance of the rolling stock. Due to the complex configuration of the train body (presence of protruding

[1] Technical Regulations of the Customs Union “On the Safety of High-Speed Rail Transport” dated 15.07.2011 with amendments as of 09.12.2011 (TR CU 002/2011). URL: http://docs.cntd.ru/document/902293437

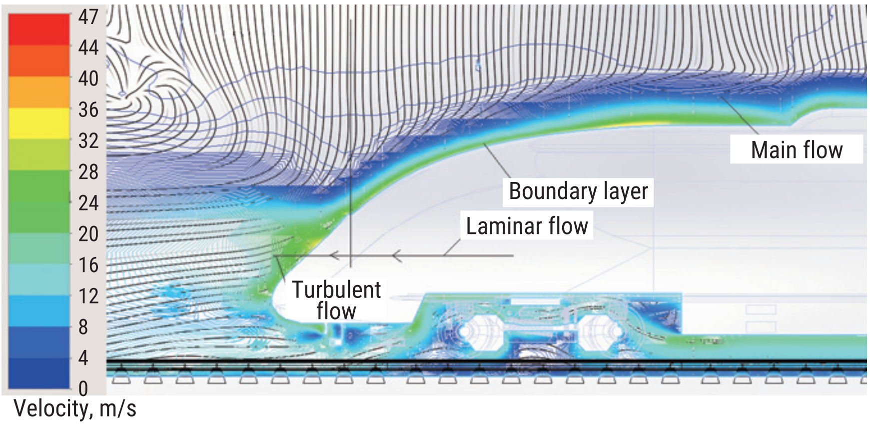

Fig. 1. Types of flows when a train is streamlined by air flow

parts, inter-car gaps, niches, etc.), turbulent flows arise. At the end of the train a rarefaction and vortex trace are formed. All these are the reasons for the increase in the forces of resistance to motion [4–7].

To analyze the aeroelastic interaction between the rolling stock and tunnel structures, one needs to use software packages that allow to realize the mathematical description of moving surfaces and volumes in a stationary air medium. The accuracy of the calculation is largely determined by how correctly the boundary layer modeling is performed.

An important point in modeling aerodynamic processes is the choice of the method of numerical modeling of turbulence. There are several main methods: Direct Numerical Simulation (DNS), Large Eddy Simulation (LES), as well as models based on Reynolds-averaged Navier – Stokes (RANS) and hybrid Shear Stress Transport (SST, shear stress transport).

Since the SST model is the most universal of these models and functions effectively for a wide class of complex gradient flows, it is used for modeling aeroelastic interaction using the program tools SolidWorks Flow Simulation [8, 9].

NUMERICAL METHOD FROZEN ROTOR

The need to reduce the calculation time without loss of accuracy on the one hand and at relatively low computational power consumption on the other made it necessary to use the Frozen Rotor method in this work. Its use allows us calculating the distribution of velocities and pressures depending on the position of an object moving along a circle. The radius of the circle along which the motion occurs is set large enough. The calculation error (primarily for rectilinear motion) will be determined, among other things, by the value of this radius due to the presence of the tangential component of velocity (*Fig. 2*).

The essence of the Frozen Rotor method is generally reduced to the selection of such an angular velocity of rotation of the coordinate system that the resulting ve-

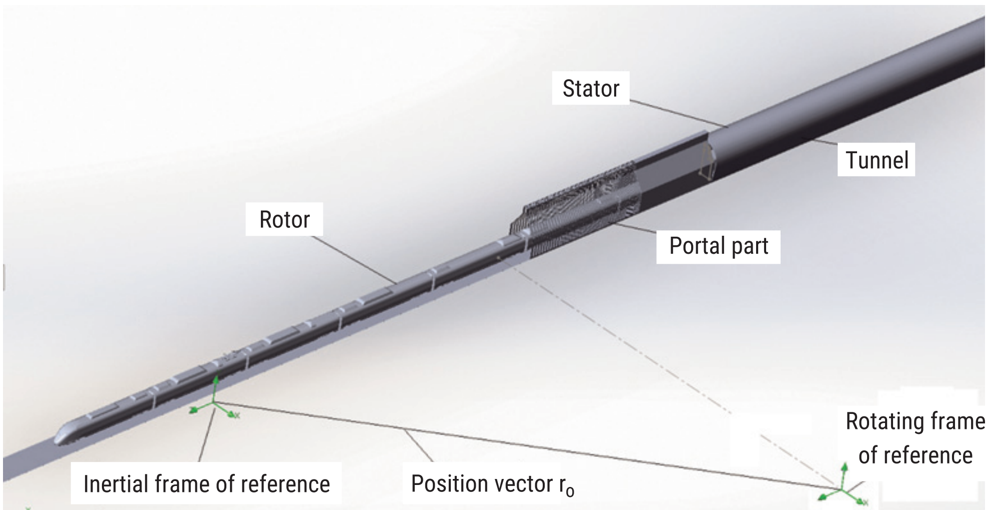

Fig. 2. Stationary and rotating frames of reference

locity of the body relative to the stationary walls of the tunnel becomes equal to zero, which will make it possible to reduce the calculation to a stationary process. When performing the transformation, the conditions of conservation of mass, momentum, and energy have to be satisfied. Centrifugal forces are applied to the air particles of the stationary region.

A serious advantage of this method is the reduction of computational time and resources consumed. This method allows us estimating the distribution of aerodynamic characteristics at different points.

CONCLUSION

The Frozen Rotor method used in combination with the large eddy method is the most promising and optimal in terms of performance and computational power consumption. It is characterized by low costs of numerical experiments compared to in-situ experiments, versatility, high speed and the possibility of performing studies at the design stage. Practically, it can be realized with the help of SolidWorks Flow Simulation software package tools.

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Modern methods for calculating transport infrastructure objects for progressive collapse

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ABSTRACT Modern Russian methods for calculating transport infrastructure objects for progressive collapse have been analysed and classified. An overview of the methods implemented in the SCAD and LIRA computer systems has been made. The transport infrastructure objects of the frame scheme have been calculated for progressive collapse with the removal of the supporting element. The results of the calculation of the frame scheme, taking into account additional parameters: damping of elements; joint work of the floor and steel structure elements; physical and geometric nonlinearity have been analysed.

Analytical, statistical and mathematical methods were applied.

It has been established that the existing software systems have sufficient functionality for calculating transport infrastructure objects in a static, dynamic, linear and non-linear problem setting. The results of calculations performed in different computer systems show different results in dynamic and quasi-static methods.

The necessity of adjusting the existing Russian building codes, taking into account the calculation procedures in modern computer systems, is revealed.

KEYWORDS: transport; construction; design; progressive collapse; buildings; structures; wireframe; element; initiating occurrence; calculation method; LIRA; computer complex

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Научная статья

Современные методы расчета объектов транспортной инфраструктуры на прогрессирующее обрушение

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АННОТАЦИЯ Проведены анализ и классификация современных российских методов расчета объектов транспортной инфраструктуры (ОТИ) на прогрессирующее обрушение. Осуществлен обзор методов, реализованных в вычислительных комплексах SCAD и ЛИРА. Рассчитаны на прогрессирующее обрушение ОТИ каркасной схемы с удалением несущего элемента. Проанализированы результаты расчета каркасной схемы с учетом дополнительных параметров: демпфирование элементов, совместная работа перекрытия и элементов стальной конструкции, физическая и геометрическая нелинейность.

Применены аналитический, статистический и математический методы.
Установлено, что существующие программные комплексы обладают достаточными функциональными возможностями для расчета ОТИ в статической, динамической, линейной и нелинейной постановке задач. Проведенные результаты расчетов в разных вычислительных комплексах показали различные результаты в динамическом и квазистатическом методах.
Выявлена необходимость корректировки существующих российских строительных норм с учетом расчетных процедур в современных вычислительных комплексах.

КЛЮЧЕВЫЕ СЛОВА: транспорт; строительство; проектирование; прогрессирующее обрушение; здания; сооружения; каркасная схема; элемент; инициирующее воздействие; метод расчета; ЛИРА; вычислительный комплекс

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INTRODUCTION

Modern Russian regulatory documents provide[1, 2, 3, 4, 5, 6] provide no complete information on the calculation methods and no examples of calculations developed in strict compliance with the standards. The documents lack a description of calculation procedures for the dynamics of progressive collapse of transport infrastructure objects, assuming that the designer has the knowledge to perform an analysis that involves a research component. Russian designers are helped by the manuals of the Federal Centre for Norming, Standardization and Conformity Assessment in Construction (FCS) [1, 2], which disclose part of the calculation method. The main problems concerning the existing normative methods is to describe them in generalized words, leaving to the designer their exact interpretation. Scientific studies by Russian [3–9] and foreign [10] authors indicate the relevance of calculations of transport infrastructure objects for progressive collapse and necessity to take into account new, previously unknown or not taken into account factors. This study analyses the regulatory framework for progressive collapse, reviews the computational complexes for progressive collapse calculations and the results of calculations using the selected methods.

RUSSIAN METHODS OF CALCULATING TRANSPORT INFRASTRUCTURE OBJECTS OF FRAME SCHEME FOR PROGRESSIVE COLLAPSE

According to SP 385.1325800.2018 “Protection of Buildings and Structures against Progressive Collapse”[1] and FAE FCS for the design of measures for the protection of buildings and structures against progressive collapse [1, 2], introduced in 2019, two calculation methods are given.

The first method. Calculation in static or dynamic formulation. The essence of the method is to perform the following steps.

1. Form the design scheme of a transport infrastructure object satisfying normal operation (*Fig. 1, a*).

2. Remove one of the elements and build a secondary design scheme with the adoption of strength and deformation characteristics in accordance with clause 5.1, loads and impacts in accordance with clause 5.2 [1] (*Fig. 1, b*).

3. Calculate the secondary circuit with the removed element. 4.

4. Determine the stress-strain state (SSS) in the elements in the secondary scheme and the criterion test of bearing capacity, as well as stability of the form.

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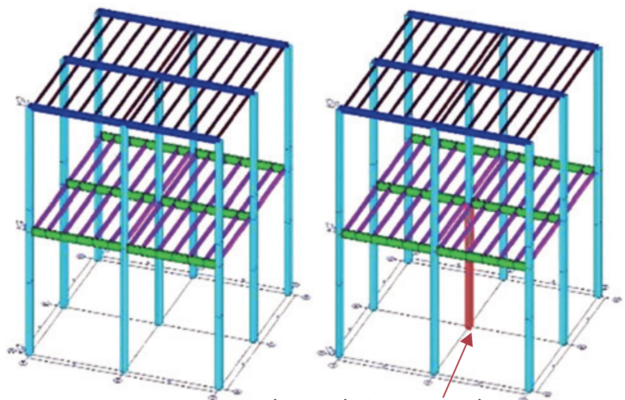

Fig. 1. Transport infrastructure object of the frame scheme:
a – primary calculation scheme; *b* – secondary scheme

5. Modify the primary and secondary design schemes in case of failure to fulfil the criterion check.

The second method. Calculation by the kinematic method of the limit equilibrium theory, the essence thereof is to perform the following steps.

1. Specify the most probable failure mechanisms of transport infrastructure object elements that have lost their support.

2. For each of the selected failure mechanisms determine the ultimate forces that can be absorbed by the cross-sections of all plastically fracturable elements and links Si, including plastic hinges.

3. Find the equidistance G_i of external forces applied to individual links of the mechanism, i.e. to individual non-destructible elements or their parts, and displacements in the direction of their action u_i.

4. Determine the work of internal forces W and external loads U on the possible displacements of the mechanism under consideration.

5. Check the condition of equilibrium $W \geq U$.

6. Change the calculation scheme in case of any failure to fulfil the equilibrium conditions.

7. Check the load-bearing capacity of the load-bearing vertical elements not located above the local failure zone.

REVIEW OF COMPUTATIONAL COMPLEXES FOR CALCULATING TRANSPORT INFRASTRUCTURE OBJECTS FOR PROGRESSIVE COLLAPSE

SCAD++ 21.1.1.1.1 (issued on 24.07.2015) computational complex used in the mode "Progressive collapse" – quasi-static, is based on the paper[1].

In the mode of calculation for progressive collapse of the transport infrastructure object in SCAD++ the instantaneous removal of destroyed elements at the dynamism coefficient equal to 2 is modeled by forces in the nodes with which the removed elements act on the rest of the scheme and applied with the opposite sign, which corresponds to the algorithm of quasi-static calculation at instantaneous removal of an element (Appendix B [1]) (pulldown analysis). If the dynamic coefficient is equal to 1, the forces at the nodes of the removed elements are assumed to be zero, and this corresponds to the gradual removal of elements from the design scheme or is equivalent to the linear static calculation of the system without collapsed elements. Additionally, it is possible to take into account the weight of collapsed structures with a given dynamic coefficient.

The calculation mode automatically takes into account the requirement that the design strength characteristics of materials are equal to their normative values. Also in the program it is possible to realize the *dynamic method* based on the method which is specified in two manuals [1, 2], it consists of three stages:

Stage 1: Obtaining the correct SSS of the structure at the moment of time before the failure of the element. The calculation is performed either in a static formulation or in a dynamic nonlinear formulation with gradual linear loading for a time interval sufficient to level dynamic effects or with increased damping.

Stage 2: Initiation impact. Removal of a structural element in a dynamic nonlinear setting for a time interval equal to 1/10 of the main period of natural oscillations of the removed element, with the appropriate design justification is allowed to adjust these values.

Stage 3: Dynamic calculation of the structure with the removed element in a nonlinear formulation by methods of direct integration of the equations of dynamics in time in explicit or implicit formulations with standard damping parameters.

The calculation of the time of the initiating impact is the key point in the dynamic method and can be performed not only taking into account the requirements [1, 2], but also using the American standards Progressive collapse analysis and design guideline (GSA, 2013) [10] or according to the reference book on dynamic impacts of B.G. Korenev, I.M. Rabinovich from 1972 (p. 95) [3], the impact of choosing one of the calculation methods is shown in the calculation part of this report "Calculation of the Frame Scheme for Progressive Collapse".

The LIRA-SAPR 2020 software package (release date – 16.03.2020) contains the tools "Stages", "Collapse", "Local failure (quasi-statics)", with the help of which the necessary scenario of transport infrastructure object collapse is set. The regulatory documents to be used in the calculation are the same[1, 2, 3, 4, 5, 6] [1, 2].

In the PC the calculation in *quasi-static* formulation is realized as follows:

- a model of a transport infrastructure object is created and design combinations of forces and (or) loads are assigned in accordance with the requirements of regulatory documents;
- to model local failure of elements in the structure the tool "Local failure (quasi-statics)" is used, which allows to assign the dynamics coefficient by selected degrees of freedom to the elements selected by the user as dismantled;
- at the stage of dismantling the structure, to select the dismantled elements to which the dynamic coefficient has been assigned.

The method of calculating the transport infrastructure object in the dynamic formulation provides for taking into account the significant effects of physical, geometric and structural nonlinearities in the destruction/collapse of individual parts of the structure and includes the steps described in the Methodological Manual of FAE FCS on pages 22–25.

In LIRA PC there is a possibility to assign to the elements of the scheme "Time of Failure from Operation" *dT* for modelling of local failure in dynamic formulation. Such assignment can be made either to a single element (e.g. a column) or to a group of elements (e.g. a wall). This will automatically generate impulse loads set in the direction opposite to the reactions of the removed elements. No impulse loads will be applied to the nodes that remained "idle" after the elements were removed (only the removed elements were adjacent to them). It is sufficient to specify only the elements. It is not necessary to specify the nodes, which makes the task less labour-intensive. The program sets the other parameters by itself and performs the calculation: assigns impulse loads (for all degrees of freedom, including rotational ones) and calculates the reactions of the removed elements. In the "Dynamics in Time" menu of the program it is necessary to set the following parameters:

- integration time (probably many times longer than the failure time, so that the system behaviour and oscillation damping can be evaluated in time);
- integration step (to obtain a point with values strictly at the boundary of the momentum growth cessation, and smaller by several times than the failure time);
- number of loading with mass weights (more convenient immediately after the last stage of assembly);
- number of load with damping characteristics;
- number of loading with dynamic loads — any free loading.

In both computational complexes it is possible to perform calculations in the formulation of the problem of local failure by quasi-static and dynamic methods in linear and nonlinear formulation (taking into account geometric, physical, genetic nonlinearity in the process of assembly and disassembly).

MATHEMATICAL EXPERIMENT: CALCULATION OF THE FRAME SCHEME OF THE TRANSPORT INFRASTRUCTURE OBJECT WITH REGARD TO PROGRESSIVE COLLAPSE

Initial data for calculation (*Fig. 2*): a transport infrastructure object of KS-2 structure category; dimensions in plan along the external axes 12 × 12 m, floor height 8 m; column grid 6 × 6 m; number of ground floors — 2; construction area of the city of Saint Petersburg; terrain type A; wind region 2: w_0 = 0,3 kPa; snow region 3: S_g = 1.5 kPa; height of monolithic slab — 90 mm; main beams BG1, BG2 and auxiliary beams BV1, BV2 made of steel C255, I-beam cross-sections on static calculation — 50B2, 40B1 and 30P, 22P respectively (BG1 and BV1 — main and auxiliary beams on the second floor, BG2 and BV2 — on the roof); columns K1 made of steel C255, section according to static calculation — I-beam 35K3 8.5 m long.

1. Quasi-static calculation method (mode "Progressive Collapse").

The results of calculation by the quasi-static method with the collapse of the central column were carried out taking into account the dynamic coefficient 2, according to SP 365 — some elements do not pass the test (*Fig. 3*).

2. Dynamic calculation method.

We choose a method for estimating the time of the initiating action.

Method 1. According to the manual FAU FCS to calculate the time of the initiating effect as 1/10 of the main period of natural oscillations of the removed element is considered scheme, in which the removed element as part of the overall scheme to obtain dynamic

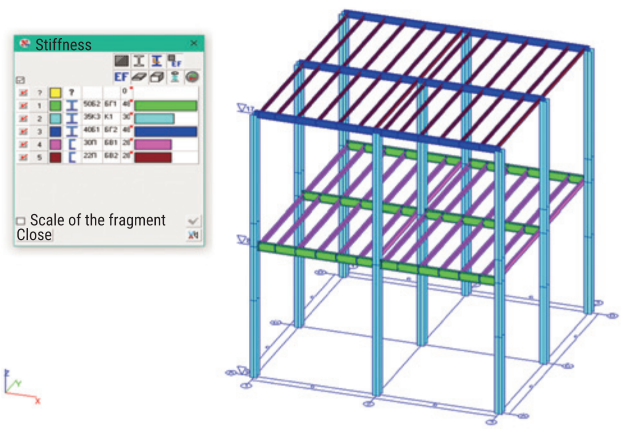

Fig. 2. Primary scheme of the metal frame of the transportation infrastructure object

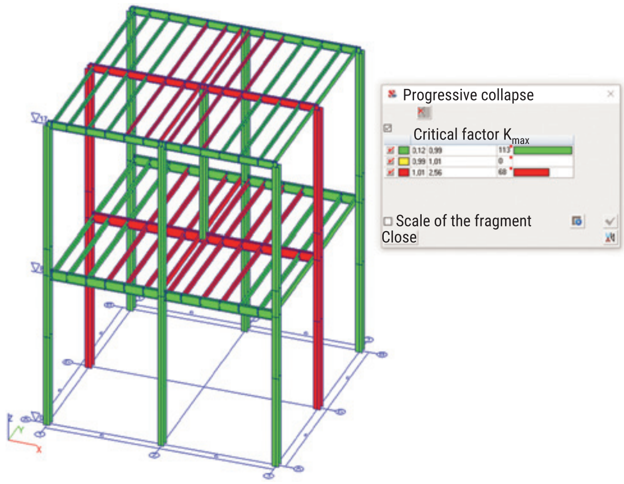

Fig. 3. Results of calculation of the transport infrastructure object by quasi-static method with collapse of the central column (secondary scheme of metal frame). Critical factor K_{max}

degrees of freedom along the length of the element is broken down in sufficient detail (detail breakdown can be recommended order 6 elements) and performed modal analysis. The results of the modal analysis are the period of oscillation of the element (the central column of the first floor T = 0.0461 s and T = 0.0325 s, the time of the initiating influence is equal t_{otk} = 0.0461 s and t_{otk} = 0.0325 s, respectively.

Method 2. According to the recommendation of American standards Progressive collapse analysis and design guideline (GSA, 2013) $t_{otk} \leq 0.1T$, where T is the period of oscillation of the structure without the retired element on the form of oscillations resembling static deformation of the system. Results of modal analysis — T = 0.40588 s, time of initiating action — $t_{otk} = 0.1T$ = 0.0406 s.

Method 3. According to the reference book on dynamic impacts by Korenev and Rabinovich of 1972 (p. 95), by analogy with the calculation of impact, if it is impossible to estimate the time of impact by calculation or experience, but there is confidence that it is small enough, it is possible to take t_{otk} = 0.001 s as a reserve of strength and rigidity of the structure.

The results of calculations by different methods showed the discrepancy between the values obtained for the displacement of the node and the maximum value (*Table*).

Based on the calculations obtained, the following conclusions can be drawn:

1. At calculation by the direct dynamic method the displacement values turned out to be 1.05 times greater (by 5 %) than by the quasi-static method.

2. At calculation by direct dynamic method the values of critical factor were 3,52 times more (by 252 %), than by quasi-static method.

3. All three methods of dynamic calculation of transport infrastructure object show close results. The highest values were found in method 1, where the oscillation period of the retired element was determined to find the time of element failure.

4. The results of calculation at different failure times of 0.2 and 0.001 s show that the response of the system and, accordingly, the SSS factors depend significantly on the loading rate, and when the failure time d_T is set in the range from 0 to $0.1T$ (the period in the scheme without a column), the change in the SSS factors is not so significant.

5. After the collapse of the central column of the transport infrastructure object the whole structure collapses, the system becomes geometrically variable – the object is completely destroyed.

6. The damping of elements, which should be taken 0.2, was not taken into account in the calculations. The used versions of the programs do not allow to set the damping coefficient in the stiffness parameters of the elements.

7. The calculations did not take into account the joint work of the reinforced concrete slab, most likely the values of displacements and the critical factor would have been less, there fore, the number of subsequently retired elements would have been less.

On the basis of the obtained results it is possible to state the necessity to improve software products for carrying out calculations of transport infrastructure objects taking into account the joint work of reinforced concrete slab and steel structure elements.

Table

Summary table of calculation results

Parameter	Dynamic method				Quasi-static method
	Method 1		Metod 2	Method 3	
	t_{otk} = 0.00461 s	t_{otk} = 0.00325 s	t_{otk} = 0.0406 s	t_{otk} = 0.001 s	
Displacement of the unit on Z	–135.04	–135.02	–133.29	–134.95	–128.43
K_{ma}	9	9	8.89	9	2.56
Number of elements with K_{max}: 0–0.99	113	113	113	113	113
Above 0.99	68	68	68	68	68

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Evaluation of the Efficiency of the Use of Hopper Cars with Aluminum Alloy Bodies

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ABSTRACT The use of aluminium and its alloys in the world history of car building began in the 30s of the last century. The paper considers various types of cars made using aluminium alloys produced in different countries, as well as an assessment of the effect of the use of cars with bodies made of aluminium alloys in the Russian Federation. The effect was determined for three parties of the transportation process: car owners, the carrier and the consignor. The paper calculated the effect of using a hopper car made of aluminium alloys model 19-1299 with an axle load of 25 tf in comparison with hopper cars with steel bodies with an axial load of 25 and 23.5 tf. It is shown that for the consignor and the carrier, the use of a car with an aluminium body by reducing the tare weight and increasing the carrying capacity brings a significant economic effect, at the same time, as for the owner of the car, there is a reasonable increase in the price of the car by 25–30 %. The purchase of cars with aluminum bodies is more expensive for the owner, and therefore it is necessary to increase the rental rate to compensate for the costs or take measures for state support.

KEYWORDS: aluminium cars; car building; aluminium alloys; innovative cars, hopper car

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Научная статья

Оценка эффективности использования вагонов-хопперов с кузовами из алюминиевых сплавов

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АННОТАЦИЯ Применение алюминия и его сплавов в мировой истории вагоностроения началось в 30-х годах прошлого века. Рассмотрены различные типы вагонов, изготовленные с помощью алюминиевых сплавов производства разных стран. Проведена оценка эффекта от применения вагонов с кузовами из алюминиевых сплавов в РФ. Эффект определялся для трех сторон перевозочного процесса: собственников вагонов, перевозчика и грузоотправителя.

Представлен расчет эффекта от применения вагона-хоппера из алюминиевых сплавов модели 19-1299 осевой нагрузкой 25 тс в сравнении с вагонами хопперами с кузовами из стали с осевой нагрузкой 25 и 23,5 тс. Для грузоотправителя и перевозчика применение вагона с алюминиевым кузовом за счет снижения веса тары и увеличения грузоподъемности приносит значительный экономический эффект в то время, как для собственника вагона имеется обоснованное увеличение цены вагона на 25 – 30 %. Приобретение вагонов с алюминиевыми кузовами обходится дороже для собственника, в связи с чем необходимо увеличить арендную ставку для компенсации затрат или принять меры по господдержке.

КЛЮЧЕВЫЕ СЛОВА: алюминиевые вагоны; вагоностроение; алюминиевые сплавы, инновационные вагоны, вагон-хоппер

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INTRODUCTION

Nowadays, aluminium and its alloys are widely used in various industries, including car building. This is due to the resumption of work on the development of cars with smaller containers through the use of new materials. Aluminium alloys have satisfactory strength characteristics with higher corrosion resistance and lower specific gravity compared to steels commonly used in car manufacturing [1–4].

In the world history of car building, they started to use aluminium in the USA in the 30s of the XX century together with the production of aluminium hopper cars. Then aluminium was used in the production of high-speed rolling stock, thanks to which it was possible to reduce the cost of traction of trains and reduce the weight of the car body. In the USSR, the production of aluminium passenger cars was limited to the ER200 train [5–7].

For freight traffic of the USSR in 1975 “Ural Car Works” manufactured a pilot gondola car with a load capacity of 66 t with a body made of aluminium alloys for transportation of coal, ore, timber and other bulk cargoes that do not require protection against atmospheric precipitation. The body and frame structure was made of special pressed profiles and panels of high-strength aluminium-magnesium alloy, hatch covers were made of steel. The catalogue-guidebook “Cars of the USSR” provides information about a 6-axle gondola with load capacity of 97 t with aluminium alloy body, but there is no information about their operation [8, 9].

In the Russian Federation, work on the creation of a car made of aluminium alloys began in the early 2000s with “Ural Car Works” producing a prototype gondola car of model 12-568 using aluminium alloys in the body structure. On the basis of aircraft building technologies of “Voronezh Joint Stock Aircraft Building Company” an attempt was made in 2005 to manufacture a gondola car from aluminium alloys, the side and end walls of which consisted of hollow pressed aluminium alloy panels [10, 11].

“Promtractor-Car”, CJSC developed a pilot hopper car made of alloy 1565h with load-carrying capacity of 80 tonnes, but serial production has not started.

At the moment the model range of cars with the use of aluminium alloys is limited. “United Car Company” has developed a hopper car with an aluminium alloy roof. “RM Rail” produced a pilot batch of model 19-1244 hopper cars made of 1565h alloy in 2017, and in 2023 developed a new model 19-1299 hopper car with a body made of 1584 aluminium alloy. “United Car Company” and “RM Rail” have developed aluminium alloy tank cars for the carriage of nitric acid, models 15-6901 and 15-1232-05. However, these developments are still unique in the “1520 area”.

At the same time, more than 200 thousand cars with aluminium alloy bodies are in operation in North America. Why are these cars profitable in America, but not in the 1520 Area?

Aluminium alloy cars manufactured in different countries are shown in the *figure* and their technical characteristics are shown in *Table 1*.

Analysing the data of Table 1, it can be concluded that the hopper car of model 19-1299, having steel frame and aluminium body, is somewhat inferior to all-aluminium foreign cars in terms of tare coefficient. The application of steel frame in production and operation, according to the developers, gives a number of advantages to such a car.

The task is to evaluate the effect of using cars with aluminium alloy bodies for three parties of the transportation process: car owners, carrier and consignor.

MATERIALS AND METHODS

Compared items and initial data

Three hopper cars of different models were chosen for efficiency calculations: 19-1299 — axle load of 25 tf, aluminium body; 19-9549 — axle load of 25 tf, steel body; 19-9814 — axle load of 23,5 tf, steel body (*Table 2*).

Fig. Aluminium alloy cars from different countries: a – Aluminum AutoFlood III (USA); b – Steel and Aluminum Triple Hopper Aggregate (USA); c – Small Cube Covered Hopper (USA); d – hopper car, model 19-1299 (Russian Federation); e – Aluminum BethGon II (USA); f – 1060 mm gauge C80H Aluminum Alloy Coal Gondola (PRC); g – tank car, model 15-6901 (Russian Federation); h – tank car, model 15-1232-05 (Russian Federation)

Table 1

Technical characteristics of aluminium alloy cars

Model (trade mark) of the car	Produced in	Type of car	Tare, t	Carrying capacity, t	Cubic capacity, m^3	Empty weight to carrying capacity ratio (tare coefficient)
Aluminum AutoFlood III	USA	Open hopper	22.40	107.32	118.93	0.21
Steel and Aluminum Triple Hopper Aggregate	USA	Open hopper	23.81	105.91	68.81	0.22
Small Cube Covered Hopper	USA	Closed hopper	23.50	106.23	92.94	0.22
19-1299	RF	Closed hopper	21.00	79.00	111.00	0.27
Aluminium BethGon II	USA	Gondola car	18.92	110.82	128.00	0.17
1060mm gauge C80H Aluminium Alloy Coal Gondola car	PRC	Gondola car	20.00	80.00	87.00	0.25
15-6901	RF	Tank car	24.50	75.00	54.78	0.33
15-1232-05	RF	Tank car	20.40	78.60	61.78	0.26

Table 2

Technical characteristics of the compared cars

Model, specific features	Axle load, tf	Carrying capacity, t	Tare, t	Tare coefficient
19-1299 aluminium body	25	79	21	0.265
19-9549 steel body	25	76	24	0.315
19-9814 steel body	23.5	70	24	0.343

Table 3

Guaranteed mechanical properties of the alloy 1581

Type of the item	Alloy	Thickness	Mechanical properties, minimum values	
			σ_n, MPa	$\sigma_{0,2}$, MPa
Flat stock	1581	1.5–6.0	345	205
		6.0–10.5	350	200
		10.5–50.0	350	190
Extruded section	1581	All dimensions	355	215

Table 4

Calculated strength characteristics

Strength class	Yield point $\sigma_т$, N/mm²	Ultimate resistance $\sigma_в$, N/mm²
345	345	490
375	375	510

The body of hopper car model 19-1299 is made of aluminium alloys 1581. Its mechanical properties are given in *Table 3*.

Car bodies of 19-9549 and 19-9814 models are made of high strength steels according to GOST 19281–2014 and GOST 19903–2015. Calculated characteristics of their strength are given in *Table 4*.

Evaluation of possible cost increases for the owner when purchasing cars with aluminium alloy structures

When purchasing new cars, the owner is faced with the question of the investment payback period and the reasonableness of the car price increase when new materials are used.

To compare strength and stiffness materials, the characteristics of specific strength (ratio of strength to specific weight) and specific stiffness (ratio of modulus of elasticity to specific weight) are used. *Table 5* summarises the specific strength and stiffness characteristics.

Analysing *Table 5*, we can conclude that aluminium alloy is 2.1 times more efficient than steel in terms of specific strength by time resistance, and 1.7 times more efficient than steel in terms of specific strength by yield strength. In terms of specific stiffness, the materials are approximately equal. Proceeding from the fact that when designing cars the main calculations are carried out on yield strength, it is possible to conclude that the elements of cars created from aluminium alloy 1581 should be about 1.7 times lighter than steel ones.

In the hopper car model 19-1299 steel body structures weighing 6.6 t were replaced by aluminium alloy structures weighing 3.6 t, i.e. the weight of the replaced structures decreased by 1.83 times. The increase in the price of material alone amounted to

$$C = 3.6t \cdot 340 \cdot 10^3\ rubles/t - 6.6t \cdot 66 \cdot 10^3\ rubles/t = 1\,224\,000 - 396\,000 = 828\,000\ rubles.$$

This is approximately 20 % of the cost of the car.

In addition, the production of aluminium structures requires the purchase of new equipment and the introduction of new welding and assembly technologies. Therefore, a reasonable increase in the price of the car should be estimated at 25–30 %, which should be paid by the owner of the car. To compensate for these costs, the owner should increase the fee for leasing the car to consignors.

Effect for the carrier from the reduction of train traction costs

In order to evaluate the effect, a comparative calculation of energy consumption and train traction costs was carried out when carrying out transport work of $3.6 \cdot 10^6$ net tonnes, which is approximately equal to the average annual work of a hopper car.

Table 5

Specific strength and stiffness values

Material	Density, t/m³	Strength class, $\sigma_в$, MPa	Yield point, $\sigma_т(\sigma_{0,2})$, N/mm²	Specific strength by ultimate tensile strength, $\sigma_в/\rho g$, km	Specific strength at yield point, $\sigma_{0,2}/\rho g$, km	Specific stiffness, $E/\rho g \cdot 10$, km
Aluminium alloy 1581	2.7	350	200	12.96	7.4	2.59
High-tensile steel 345	7.8	480	345	6.11	4.39	2.54

Table 6

Calculations of energy required to perform transport works 3,6•10⁶ tkm net

Model	$(1 + k_т)$	Specific resistance w, n/t	Transport works A, tkm net	Energy consumption $П_э$, GJ	Saved energy $Δ_э$, GJ
19-1299	1,265	12,39	$3{,}6 \cdot 10^6$	56,42	–
19-9549	1,315	12,39	$3{,}6 \cdot 10^6$	58,65	2,23
19-9814	1,343	12,8	$3{,}6 \cdot 10^6$	59,9	3,48

Table 7

Results of calculation of savings from the use of aluminium alloy hopper car in loaded mode

Comparison vs cars with axle load, tf	Energy saving for empty car traction, GJ	Electricity savings, kWh	Cost of saved electricity at the price of 4 rubles/kWh	Diesel fuel savings, kg	Cost of saved diesel fuel at the price of 45 rubles/kg	Total traction savings
25	2.23	1756	7,024	66.09	2,974	9,998
23.5	3.43	2701	10,804	103.14	4,641	15,445

Table 8

Results of calculation of savings from the use of aluminium alloy hopper car in empty mode

Comparison vs cars with axle load, tonnes	Energy saving for empty car traction, GJ	Electri-city savings, kWh	Cost of saved electricity at the price of 4 rubles/kWh	Diesel fuel savings, kg	Cost of saved diesel fuel at the price of 45 rubles/kg	Total traction savings
25	2.25	1772	7,088	66.69	3,001	10,089
23.5	5.79	4560	18,240	171.61	7,722	25,962

Energy costs for overcoming the main resistance to movement were determined in accordance with the following papers [12, 13]:

$$П_{э\ гр} = (1 + k_т)w(v, q_0)A, \quad (1)$$

where $k_т = m_т/m_г$ — car tare coefficient; v — velocity; $w(v, q_0)$ – basic specific resistance of the car, depending on the average speed v and axle load q_0; $A = 3{,}6 \cdot 10^6$ *tkm net* — conditional volume of transport works per year (*Table 6*).

The results of calculation of energy resources saving in loaded mode for the volume of performed transport work of $3.6 \cdot 10^6$ net tonnes are given in *Table 7*. Here it is assumed that 85 % of the work is performed on electric traction, 15 % — on diesel traction.

The results of energy calculation for empty cars transportation when carrying out transport works of $3.6 \cdot 10^6$ net tonne kilometres are given in *Table 8*.

Total savings from the use of aluminium alloy hopper car are presented in *Table 9*.

This calculation explains the popularity of aluminium cars in North America. Trains there are driven by diesel locomotives and the cost of diesel fuel is 4 times higher. For American railways, the value of saved fuel would be 1831 kg and the cost in rubles would be 329,690 rubles, i.e. the effect is almost 8 times greater. But for Russian railways, the effect is also tangible.

Table 9

Results of calculation of traction savings from the use of aluminium alloy hopper car in loaded and empty modes

Comparison vs cars with axle load, tf	Savings, rubles
25	20,087
23.5	41,407

Effect for the carrier from change in railway track maintenance costs as a result of operation of cars with aluminium body with smaller tare

The change in railway maintenance costs as a result of the operation of cars with aluminium body is carried

[1] Methodology for assessing the economic efficiency of the operation of innovative freight cars on the railway infrastructure of Russian Railways (approved by the Order of the Ministry of Transport of the Russian Federation No.457 dated 23.10.2017).

Table 10

Characteristics of the cars compared

Model, specific features	Axle load, tf		Carrying capacity, t	Tare, t	Relative change in track load k_τ	
	loaded	empty			loaded	empty
19-1299 aluminium body	25	5.25	79	21	–	–
19-9549 steel body	25	6	76	24	1	1.143
19-9814 steel body	23.5	6	70	24	0.94	1.143

Table 11

Calculation of change in railway maintenance costs in loaded mileage

Model	Cargo weight, t	Tare weight, t	Loaded mileage, km	Tkm gross	Damage rate of railway track $k_{\tau\,тр}$	$(m^а_г + m^а_т)L^а_{тр}$, tkm	$k_\tau(m^с_г + m^с_т)L^с_{тр}$, tkm gross	Change in track impact, tkm	Change in expenses (at an expense rate of 0.02213 rubles/tonne), rubles
19-1299	79	21	45 570	4 557 000	1	4 557 000	–	–	–
19-9549	76	24	47 368	4 736 800	1	–	4 736 800	–179 800	–3,978
19-9814	70	24	51 428	4 834 200	0.78	–	3 770 676	+ 786 324	+ 17,401

out for empty and loaded cars and is determined by formulas in accordance with the paper[1]:

- when loaded

$$\Delta E_{гр} = e_{ткм}((m^а_г + m^а_т)L^а_{гр} - k_{\tau\,гр}(m^с_г + m^с_т)\,L^с_{гр}); \qquad (2)$$

- when empty

$$\Delta E_{пор} = e_{ткм}(m^а_т L^а_{пор} - k_{\tau\,пор} m^с_т L^с_{пор}), \qquad (3)$$

where $e_{ткм}$ – consumption rate per gross metered tonne kilometre in freight traffic, rubles/tkm; $m^с_г$ and $m^а_г$ – weight of cargo in steel and aluminium car, respectively; $m^с_т$ and $m^а_т$ – tare weight of steel and aluminium car; $k_{\tau\,пор}$ and $k_{\tau\,гр}$ — coefficients reflecting the change in the impact of vertical and horizontal forces of an aluminium car on the track compared to a steel car in empty and loaded runs.

Coefficient k_τ is defined from the expression

$$k_\tau = \gamma_B \cdot \left(\frac{Q_1}{Q_2}\right)^\chi + \gamma_{VB} \cdot \left(\frac{\sqrt{Q_1^2 + Y_1^2}}{\sqrt{Q_2^2 + Y_2^2}}\right)^\chi, \qquad (4)$$

where γ_B — share of railway track damage associated with the impact of vertical forces — railway alignment, wear of rail pads, filler pieces, filler piece pads, sleepers (ranges from 0.60 to 0.65); Q_1/Q_2 — ratio of the maximum probable vertical dynamic force exerted by the wheels of the innovative car Q_1 to the same strength of the analogue car Q_2, which shows how much the impact on the path has changed in the vertical direction; the force relations are raised to a degree of χ ($\chi = 4$), which takes into account the accepted relationship between the force impact on the railway track *F* and the damage to its components: $D \sim F^\chi$; $\gamma_{ВБ}$ — share of railway track damage associated with the total impact of vertical and lateral forces — straightening, track gauge adjustment, rail, bolt and screw replacements, wear of lining pads in steep curves, insulating elements of fastenings (makes 0.35–0.40); $\frac{\sqrt{Q_1^2 + Y_1^2}}{\sqrt{Q_2^2 + Y_2^2}}$ – ratio, which shows how much the impact on the track has changed in the vertical and horizontal directions in total; Y_1, Y_2 — maximum probable lateral dynamic force of the car and its analogue, respectively.

Due to the lack of experimental data, the changes in vertical and horizontal forces were determined theoretically, taking into account that their changes are directly proportional to the axial load.

This representation is an estimate from above, because the results of experiments with bogies with a load of 25 tonnes showed a smaller increase in the coefficient of $k_т$.

Expenditure rate RS-51 for measuring gross tonnes per 1000 gross tonnes of track structure was assumed to be average for the network and amounted to 22.13 rubles per 1000 gross tonnes[2].

The initial data for the calculation are shown in *Table 10–13*.

[2] Expenditure rates determined on the basis of the volume-dependent expenses of “Russian Railways”, JSC for transportation activities // “Russian Railways”, JSC. 2023.

Table 12

Calculation of change in railway maintenance costs in empty mileage

Model	Tare weight, t	Loaded mileage, km	Tkm gross	Damage rate of railway track $k_{\tau тр}$	$(m_г^а + m_т^а)L_{тр}^а$, tkm	$k_\tau(m_г^с + m_т^с)L_{тр}^с$, tkm gross	Change in track impact, tkm	Change in expenses (at an expense rate of 0.02213 rubles/tonne), rubles
19-1299	21	45 570	956 970	1	956 970	–	–	–
19-9549	24	47 368	1 136 832	1,7	–	1 932 600	–975 630	–21,590
19-9814	24	51 428	1 234 272	1,7	–	2 098 262	–1 141 290	–25,256

Table 13

Results of calculation of savings from application of aluminium alloy hopper car in loaded and empty modes from reduction of track maintenance costs

Comparison vs cars with axle load, tf	Savings, rubles
25	25,568
23.5	7,855

The reduction in the cost of maintaining the railway track structure for an aluminium alloy hopper car with an axle load of 25 tf and a tare coefficient of 0.265 will be:

- compared to a steel hopper car with an axle load of 25 tonnes and tare coefficient of 0.315–0.0025 rubles/km (11 % of the cost rate);
- compared to a steel hopper car with 23.5 tonnes axle load and tare coefficient 0.343–0.0007 rubles/tkm (3 % of the cost rate).

So, the use of cars with aluminium alloy body brings effect to the carrier both in terms of reduction of train traction costs and track maintenance costs.

Effect for the consignor from reduction of tariff costs when cargo is transported in a car with a higher carrying capacity

The peculiarity of the current Price List is the independence of the tariff from the amount of cargo in the car, the tariff mainly depends on the distance of carriage. Therefore, at the considered transport work of $3{,}6 \cdot 10^6$ tkm net the consignor, sending the cargo in a car with a higher carrying capacity, reduces the number of consignments and due to this saves expenses for tariff payment in loaded mode. The results of calculations are given in *Table 14*.

Thus, the consignor receives the main savings from the use of cars with increased load capacity.

RESULTS OF THE STUDY

The use of cars with aluminium body brings benefits to the freight carrier and consignor, as well as to the national economy in general. Cost savings for the annual volume of transport work $3.6 \cdot 10^6$ tkm net when operating an aluminium hopper car of 12-1299 model will amount to:

- for the carrier due to saving of fuel costs for traction of trains in comparison with steel cars with axial load of 25 tf – 20,087 rubles, in comparison with cars with axial load of 23.5 tf – 41,407 rubles;
- for the carrier due to reduction of track maintenance costs in comparison with steel cars with axial load of 25 tf – 25,568 rubles, in comparison with cars with axial load of 23.5 tf – 7,855 rubles;
- for the consignor due to reduction of expenses for tariff payment in comparison with steel cars with axial load of 25 tf – 188,980 rubles, in comparison with cars with axial load of 23.5 tf – 416,940 rubles.

Table 14

Results of calculation of savings from the use of hopper car due to reduction of tariff costs (range ~1700 km)

Car model	Carrying capacity, t	Loaded mileage, km	Increase in length of loaded mileage, km	Savings on tariff payment for loaded mileage*, rubles	Savings on payment of empty mileage tariff*, rubles	Total
19-1299	79	45 570	–	–	–	–
19-9549	76	47 368	1798	87,720	51,260	138,980
19-9814	70	51 428	5858	263,160	153,780	416,940
Note: * – calculation according to ETRAN program.						

CONCLUSION

It is more expensive for the car owner to purchase cars with aluminium bodies. In order to compensate for the increased costs, it is advisable for the car owner to increase the lease rate or to take measures for state support for the purchase of cars with smaller containers.

The widespread use of aluminium alloy cars in North America is due to energy savings for traction by diesel locomotives, which have lower efficiency compared to electric locomotives, and the high cost of diesel fuel compared to fuel prices in the Russian Federation.

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